PB-237 612

Background Information for Standards of Performance Primary Aluminum Industry. Volume I: Proposed Standards

Environmental Protection Agency

October 1974

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

PB

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completion)

1. REPORT NO. EPA-450/2-74-020a	2. PB 237 612
4. TITLE AND SUBTITLE: BACKGROUND INFORMATION FOR STANDARDS OF PERFORMANCE: Primary Aluminum Plants, Volume 1, PROPOSED STANDARDS	5. REPORT DATE: October 1974
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, N.C. 27711	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This volume is the first of a series on standards of performance for primary aluminum plants. This volume presents the proposed standards and the rationale for the degree of control selected. The volume also discusses the analytical methods for sampling emissions and the environmental and economic impact of the standards.

PRICES SUBJECT TO CHANGE

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air pollution Pollution control Performance standards Primary Aluminum Plants	Air pollution control	

18. DISTRIBUTION STATEMENT: Unlimited	19. SECURITY CLASS (This Report): Unclassified	21. NO. OF PAGES: 123
	20 SECURITY CLASS (This page): Unclassified	22. PRICE: $5.25/2.25

EPA Form 2220-1 (9-73)

EPA-450/2-74-020a

BACKGROUND INFORMATION FOR STANDARDS OF PERFORMANCE: PRIMARY ALUMINUM INDUSTRY VOLUME 1: PROPOSED STANDARDS

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

October 1974

This report is issued by the Environmental Protection Agency to report technical data of interest to a limited number of readers. Copies are available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - as supplies permit - from the Air Pollution Technical Information Center, Environmental Protection Agency, Research Triangle Park, North Carolina 27711; or, for a fee, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

Publication No. EPA-450/2-74-020a

PREFACE

A. Purpose of this Report

Standards of performance under section 111 of the Clean Air Act[1/] are proposed only after a very detailed investigation of air pollution control methods available to the affected industry and the impact of their costs on the industry. This report summarizes the information obtained from such a study of the primary aluminum industry. It is being distributed in connection with formal proposal of standards for that industry in the Federal Register. Its purpose is to explain the background and basis of the proposal in greater detail than could be included in the Federal Register, and to facilitate analysis of the proposal by interested persons, including those who may not be familiar with the many technical aspects of the industry. For additional information, for copies of documents (other than published literature) cited in the Background Information Document, or to comment on the proposed standards, contact Mr. Don R. Goodwin, Director, Emission Standards and Engineering Division, United States Environmental Protection Agency, Research Triangle Park, North Carolina 27711 [(919)688-8146].

B. Authority for the Standards

Standards of performance for new stationary sources are promulgated in accordance with section 111 of the Clean Air Act (42 USC 1857c-6), as amended in 1970. Section 111 requires

---

1/ Sometimes referred to as "new source performance standards" (NSPS).

the establishment of standards of performance for new stationary sources of air pollution which "... may contribute significantly to air pollution which causes or contributes to the endangerment of public health or welfare." The Act requires that standards of performance for such sources reflect "... the degree of emission limitation achievable through the application of the best system of emission reduction which (taking into account the cost of achieving such reduction) the Administrator determines has been adequately demonstrated." The standards apply only to stationary sources, the construction or modification of which commences after regulations are proposed by publication in the Federal Register.

Section 111 prescribes three steps to follow in establishing standards of performance.

1. The Administrator must identify those categories of stationary sources for which standards of performance will ultimately be promulgated by listing them in the Federal Register.
2. The regulations applicable to a category so listed must be proposed by publication in the Federal Register within 120 days of its listing. This proposal provides interested persons an opportunity for comment.
3. Within 90 days after the proposal, the Administrator must promulgate standards with any alterations he deems appropriate.

It is important to realize that standards of performance, by themselves, do not guarantee protection of health or welfare; that is, they are not designed to achieve any specific air quality levels. Rather, they are designed to reflect best demonstrated technology (taking into account costs) for the affected sources. The overriding purpose of the collective body of standards is to maintain existing air quality and to prevent new pollution problems from developing.

Previous legal challenges to standards of performance for portland cement plants, steam generators, and sulfuric acid plants have resulted in several court decisions[2/] of importance in developing future standards. In those cases, the principal issues were whether EPA: (1) made reasoned decisions and fully explained the basis of the standards, (2) made available to interested parties the information on which the standards were based, and (3) adequately considered significant comments from interested parties.

Among other things, the court decisions established: (1) that preparation of environmental impact statements is not necessary for standards developed under section 111 of the Clean Air Act because, under that section, EPA must consider any counter-productive environmental effects of a standard in determining what system of control is "best;" (2) in considering costs it is not necessary to provide a cost-benefit analysis;

2/ Portland Cement Association v Ruckelshaus, 486 F. 2nd 375 (D.C. Cir. 1973); Essex Chemical Corp. v Ruckelshaus, 486 F. 2nd 427 (D.C. Cir. 1973).

(3) EPA is not required to justify standards that require different levels of control in different industries unless such different standards may be unfairly discriminatory; and (4) it is sufficient for EPA to show that a standard can be achieved rather than that it has been achieved by existing sources.

Promulgation of standards of performance does not prevent State or local agencies from adopting more stringent emission limitations for the same sources. On the contrary section 116 of the Act (42 USC 1857-D-1) makes clear that States and other political subdivisions may enact more restrictive standards. Furthermore, for heavily polluted areas, more stringent standards may be required under section 110 of the Act (42 USC 1857c-5) in order to attain or maintain national ambient air quality standards prescribed under section 109 (42 USC 1857c-4). Finally, section 116 makes clear that a State may not adopt or enforce less stringent standards than those adopted by EPA under section 111.

Although it is clear that standards of performance should be in terms of limits on emissions where feasible,[3/] an alternative method of requiring control of air pollution is sometimes necessary. In some cases physical measurement of emissions from a new source may be impractical or exorbitantly expensive.

3/ "'Standards of performance,' ... refers to the degree of emission control which can be achieved through process changes, operation changes, direct emission control, or other methods. The Secretary [Administrator] should not make a technical judgment as to how the standard should be implemented. He should determine the achievable limits and let the owner or operator determine the most economical technique to apply." Senate Report 91-1196.

For example, emissions of hydrocarbons from storage vessels for petroleum liquids are greatest during storage and tank filling. The nature of the emissions (high concentrations for short periods during filling and low concentrations for longer periods during storage) and the configuration of storage tanks make direct emission measurement highly impractical. Therefore, a more practical approach to standards of performance for storage vessels has been equipment specification.

C. Selection of Categories of Stationary Sources

Section 111 directs the Administrator to publish and from time to time revise a list of categories of sources for which standards of performance are to be proposed. A category is to be selected "... if [the Administrator] determines it may contribute significantly to air pollution which causes or contributes to the endangerment of public health or welfare."

Since passage of the Clean Air Amendments of 1970, considerable attention has been given to the development of a system for assigning priorities to various source categories. In brief, the approach that has evolved is as follows.

First, we assess any areas of emphasis by considering the broad EPA strategy for implementing the Clean Air Act. Often, these "areas" are actually pollutants which are primarily emitted by stationary sources. Source categories which emit these pollutants are then evaluated and ranked by a process involving

such factors as (1) the level of emission control (if any) already required by State regulations; (2) estimated levels of control that might result from standards of performance for the source category; (3) projections of growth and replacement of existing facilities for the source category; and (4) the estimated incremental amount of air pollution that could be prevented, in a preselected future year, by standards of performance for the source category.

After the relative ranking is complete, an estimate must be made of a schedule of activities required to develop a standard. In some cases, it may not be feasible to immediately develop a standard for a source category with a very high priority. This might occur because a program of research and development is needed or because techniques for sampling and measuring emissions may require refinement before study of the industry can be initiated. The schedule of activities must also consider differences in the time required to complete the necessary investigation for different source categores. Substantially more time may be necessary, for example, if a number of pollutants must be investigated in a single source category. Even late in the development process the schedule for completion of a standard may change. For example, inability to obtain emission data from

well-controlled sources in time to pursue the development process in a systematic fashion may force a change in scheduling.

Selection of the source category leads to another major decision: determination of the types of sources or facilities to which the standard will apply. A source category often has several facilities that cause air pollution. Emissions from some of these facilities may be insignificant and, at the same time, very expensive to control. An investigation of economics may show that, within the costs that an owner could reasonably afford, air pollution control is better served by applying standards to the more severe pollution problems. For this reason (or perhaps because there may be no adequately demonstrated system for controlling emissions from certain facilities), standards often do not apply to all sources within a category. For similar reasons, the standards may not apply to all air pollutants emitted by such sources. Consequently, although a source category may be selected to be covered by a standard of performance, treatment of some of the pollutants or facilities within that source category may be deferred.

D. Procedure for Development of Standards of Performance

Congress mandated that sources regulated under section 111 of the Clean Air Act be required to utilize the best practicable air pollution control technology that has been adequately

demonstrated at the time of their design and construction. In so doing, Congress sought to:

1. maintain existing high-quality air,
2. prevent new air pollution problems, and
3. ensure uniform national standards for new facilities.

The selection of standards of performance to achieve the intent of Congress has been surprisingly difficult. In general, the standards must (1) realistically reflect best demonstrated control practice; (2) adequately consider the cost of such control; (3) be applicable to existing sources that are modified as well as new installations; and (4) meet these conditions for all variations of operating conditions being considered anywhere in the country.

A major portion of the program for development of standards is spent identifying the best system of emission reduction which "has been adequately demonstrated" and quantifying the emission rates achievable with the system. The legislative history of section 111 and the court decisions referred to above make clear that the Administrator's judgment of what is adequately demonstrated is not limited to systems that are in actual routine use. Consequently, the search may include a technical assessment of control systems which have been adequately demonstrated but for which there is limited operational experience. To date, determination of the "degree of emission limitation achievable"

has been commonly based on (but not restricted to) results of tests of emissions from existing sources. This has required worldwide investigation and measurement of emissions from control systems. Other countries with heavily populated, industrialized areas have sometimes developed more effective systems of control than those used in the United States.

Because the best demonstrated systems of emission reduction may not be in widespread use, the data base upon which the standards are established will necessarily be somewhat limited. Test data on existing well-controlled sources are an obvious starting point in developing emission limits for new sources. However, since the control of existing sources generally represents retrofit technology or was originally designed to meet an existing State or local regulation, new sources may be able to meet more stringent emission standards. Accordingly, other information must be considered and judgment is necessarily involved in setting proposed standards.

Since passage of the Clean Air Amendments of 1970, a process for the development of a standard has evolved. In general, it follows the guidelines below.

1. Emissions from existing well-controlled sources are measured.
2. Data on emissions from such sources are assessed with consideration of such factors as: (a) the representativeness

of the source tested (feedstock, operation, size, age, etc.); (b) the age and maintenance of the control equipment tested (and possible degradation in the efficiency of control of similar new equipment even with good maintenance procedures); (c) the design uncertainties for the type of control equipment being considered; and (d) the degree of uncertainty affecting the judgment that new sources will be able to achieve similar levels of control.

3. During development of the standards, information from pilot and prototype installations, guarantees by vendors of control equipment, contracted (but not yet constructed) projects, foreign technology, and published literature are considered, especially for sources where "emerging" technology appears significant.
4. Where possible, standards are set at a level that is achievable with more than one control technique or licensed process.
5. Where possible, standards are set to encourage (or at least permit) the use of process modifications or new processes as a method of control rather than "add-on" systems of air pollution control.
6. Where possible, standards are set to permit use of

systems capable of controlling more than one pollutant (for example, a scrubber can remove both gaseous and particulate matter emissions, whereas an electrostatic precipitator is specific to particulate matter).

7. Where appropriate, standards for visible emissions are established in conjunction with mass emission standards. In such cases, the standards are set in such a way that a source meeting the mass emission standard will be able to meet the visible emission standard without additional controls. (In some cases, such as fugitive dust, there is no mass standard).

Finally, when all pertinent data are available, judgment is again required. Numerical tests may not be transposed directly into regulations. The design and operating conditions of those sources from which emissions were actually measured cannot be reproduced exactly by each new source to which the standard of performance will apply.

E. How Costs are Considered

Section 111 of the Clean Air Act requires that cost be considered in setting standards of performance. To do this requires an assessment of the possible economic effects of implementing various levels of control technology in new plants within a given industry. The first step in this analysis requires the generation of estimates of installed capital costs and annual

operating costs for various demonstrated control systems, each control system alternative having a different overall control capability. The final step in the analysis is to determine the economic impact of the various control alternatives upon a new plant in the industry. The fundamental question to be addressed in this step is whether or not a new plant would be constructed given that a certain level of control costs would be incurred. Other issues that would be analyzed in this step would be the effects of control costs upon product prices and the effects on product and raw material supplies and producer profitability.

The economic impact upon an industry of a proposed standard is usually addressed both in absolute terms and by comparison with the control costs that would be incurred as a result of compliance with typical existing State control regulations. This incremental approach is taken since a new plant would be required to comply with State regulations in the absence of a Federal standard of performance. This approach requires a detailed analysis of the impact upon the industry resulting from the cost differential that usually exists between the standard of performance and the typical State standard.

It should be noted that the costs for control of air pollutants are not the only control costs considered. Total environmental costs for control of water pollutants as well

as air pollutants are analyzed wherever possible.

A thorough study of the profitability and price-setting mechanisms of the industry is essential to the analysis so that an accurate estimate of potential adverse economic impacts can be made. It is also essential to know the capital requirements placed on plants in the absence of Federal standards of performance so that the additional capital requirements necessitated by these standards can be placed in the proper perspective. Finally, it is necessary to recognize any constraints on capital availability within an industry as this factor also influences the ability of new plants to generate the capital required for installation of the additional control equipment needed to meet the standards of performance.

The end result of the analysis is a presentation of costs and potential economic impacts for a series of control alternatives. This information is then a major factor which the Administrator considers in selecting a standard.

F. Impact on Existing Sources

Proposal of standards of performance may affect an existing source in either of two ways. First, if modified after proposal of the standards, with a subsequent increase in air pollution, it is subject to standards of performance as if it were a new source. (Section 111 of the Act defines a new source as "any stationary source, the construction or

modification of which is commenced after the regulations are proposed.")[4/]

Second, promulgation of a standard of performance requires States to establish standards of performance for the same pollutant for existing sources in the same industry under section 111(d) of the Act; unless the pollutant limited by the standard for new sources is one listed under section 108 (requiring promulgation of national ambient air quality standards) or one listed as a hazardous pollutant under section 112. If a State does not act, EPA must establish such standards. Regulations prescribing procedures for control of existing sources under section 111(d) will be proposed as Subpart B of 40 CFR Part 60.

G. Revision of Standards of Performance

Congress was aware that the level of air pollution control achievable by any industry may improve with technological advances. Accordingly, section 111 of the Act provides that the Administrator may revise such standards from time to time. Although standards proposed and promulgated by EPA under section 111 are designed to require installation of the "... best system of emission reduction ... (taking into account the cost)..." the standards will be reviewed periodically. Revisions will be proposed and promulgated as necessary to assure that the standards

4/ Specific provisions dealing with modifications to existing facilities are being proposed by the Administrator under the General Provisions of 40 CFR Part 60.

continue to reflect the best systems that become available in the future. Such revisions will not be retroactive but will apply to stationary sources constructed or modified after proposal of the revised standards.

H. Why Standards of Performance for Fluorides?

Two questions are basic to the control of fluorides: why control them and why do so with section 111?

The deleterious effects of fluoride on both animals and vegetation have been extensively documented.[5/] The effect on animals is through the digestive tract when relatively large quantities of contaminated vegetation are ingested. Citizens, both privately and in groups, have sought relief from fluoride damage through suits against the alleged industrial sources. In one case, a citizens' group sent to EPA data which support the need for Federal regulation of fluorides. State agencies have recorded and acted on numerous public complaints on the adverse effects of fluorides on the growth, yield, quality, and appearance of marketable goods such as fruit, grains, leafy vegetables, pine trees, ornamental plants, and dairy cattle.

In determining that there is a need to control fluoride emissions into the atmosphere, the Administrator relied heavily upon the report Fluorides, which was prepared for the Agency by

5/ National Academy of Sciences, Fluorides, prepared for EPA under Contract No. CPA 70-42, Washington, D. C. 20418, 1971.

the National Academy of Sciences in 1971. In preparing this report, the Academy made a concerted effort to evaluate the world literature on the subject and distill the best scientific knowledge available on the biological effects of fluorides. This report concludes: "Current knowledge indicates that airborne fluoride presents no direct hazard to man, except in industrial exposure. However, through the commercial, aesthetic, and ecologic functions of plants, fluoride in the environment may indirectly influence man's health and well being." After considering the available information on fluorides, the Administrator has concluded that, even though present evidence indicates that fluorides in the range of ambient concentrations encountered under worst conditions do not damage human health through inhalation, they do present a serious risk to public welfare[6/] and warrant control. Fluoride emissions affect public welfare not only through their effects on aesthetic values, but also through a decrease in the economic value of crops which are damaged by exposure to fluorides and through adverse effects on the health of animals ingesting vegetation which has accumulated excessive amounts of fluorides.

6/ As used in the Clean Air Act, the term "effects on welfare" includes, but is not limited to, ". . . effects on soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well being." [See section 302(h) 42 U.S.C. 1857h(h) as amended.]

Private citizens and citizens' groups have actively sought means to alleviate fluoride damage. One citizens' group, Center for Science in the Public Interest, has written the Agency describing at great length the need for fluoride regulations. A number of lawsuits have been initiated which are concerned with fluoride effects on agricultural products, and at least 20 citizens' suits have been filed against aluminum plants that emit fluorides.

The Administrator's decision to control fluoride emissions at the national level was based on the following:

1. The present national ambient air quality standards for particulate matter, standing alone, would not provide adequate welfare protection against the effects of fluoride for two reasons: (a) fluorides are emitted as both particulate matter and gases, and (b) since the ambient standard is for "non-specific" particulate matter, compliance with that standard would not ensure fluoride concentrations sufficiently low to prevent damage.
2. Although many states have adopted fluoride control regulations, major sources of fluoride emissions exist in several states with no fluoride regulations.
3. A uniform national standard of performance for new sources would discourage movement of major fluoride emitters to states with no fluoride regulations.

4. Primary aluminum reduction plants, one of the major sources of fluoride emissions, are commonly located near major waterways that comprise borders between states. The potential for interstate conflict concerning control of emissions from such plants has prompted Federal investigations in the past, and in at least one case a state has requested initiation of abatement conference proceedings under section 115 of the Act [42 U.S.C. 1857d].

An EPA report entitled "Preferred Standards Path Report for Fluorides" (November 1972) contains a detailed discussion of the advantages and disadvantages of each regulatory option provided to the Administrator under the Act to control fluoride emissions on a national level.[7/] In general, the Administrator concluded that fluorides should be regulated under section 111 of the Act for the following reasons:

1. In contrast with the problems presented by the six pollutants for which national ambient air quality standards have been promulgated, the fluoride problem is highly localized in the vicinity of major point sources in agricultural areas and is not complicated by the presence of numerous mobile sources. Promulgating a national ambient air quality standard for fluorides

7/ A copy of this report is available for inspection during normal business hours at the Freedom of Information Center, Environmental Protection Agency, 401 M Street, S.W., Washington, D. C.

under section 10? would require states to submit implementation plans to attain and maintain such standards. Because of the complex problems involved in relating emissions to ambient levels, most plans would include regulations based on best demonstrated control technology. The same result can be accomplished more directly and efficiently through the promulgation of standards of performance.

2. Adopting national standards of performance would be more compatible with existing state regulations than adopting ambient air quality standards.
3. Since accumulation of fluorides during chronic exposure to low-level ambient concentrations may result in fluoride levels detrimental to either vegetation or to the health of animals consuming the vegetation, an ambient standard for fluorides may not in fact ensure prevention of adverse welfare effects.
4. An ambient fluoride standard stringent enough to ensure complete protection against any welfare effects might require closure of major sources of fluoride emissions. A more practical and feasible approach is to minimize fluoride damage through best demonstrated control technology; i.e., by regulating fluoride emissions under section 111.

5. The National Academy of Sciences report indicates that because fluorides present no direct hazard to human health, the provisions of section 112 for controlling fluorides as a hazardous air pollutant could not be used.

Promulgation of the proposed standards of performance for fluorides will affect existing sources as explained in section F of this preface. Of particular note is that states will be required to establish standards for the control of fluorides from existing sources under section 111(d) of the Act. The resulting control may not be as stringent as that required by the standards of performance for new sources. As indicated previously, regulations prescribing procedures for control of existing sources under section 111(d) will be proposed as Subpart B of 40 CFR Part 60.

TABLE OF CONTENTS

Section	Page
Summary of Proposed Standards	1
Description of Process	2
Emissions and Methods of Control	9
Rationale for Proposed Standards	14
Selection of Pollutants for Control	14
Selection of Units for the Standard	15
Selection of Sampling and Analytical Techniques	15
Discussion	20
A. Determination of Affected Facilities	20
B. Determination of Best Control Techniques for Aluminum Production	21
C. Data Base - Primary Emissions	28
D. Data Base - Secondary Emissions	33
E. Data Base - Carbon Anode Bake Plant Emissions	37
F. Cost Analysis of Alternative Fluoride Control Systems	41
G. Economic Analysis of Proposed Standards	64
H. Summary	94
References	97

PRIMARY ALUMINUM REDUCTION PLANTS

SUMMARY OF PROPOSED STANDARDS

Standards of performance are being proposed for new primary aluminum reduction plants. The proposed standards would limit emissions of total fluorides and visible emissions from potroom(s) which house primary aluminum reduction cells and from anode bake plants. The entire plant is the affected facility.

The standards apply at the point(s) where emissions are discharged from the air pollution control system or from the affected facility if untreated by an air pollution control system.

The proposed standards would limit emissions to the atmosphere as follows:

Total Fluorides

No more than 1 kg of total fluorides per metric ton of aluminum (or aluminum equivalent) produced (2.00 lbs/ton) from the primary aluminum reduction plant, including the carbon anode bake plant.

Visible Emissions

1. Less than 10 percent opacity from the potroom.
2. Less than 20 percent opacity from the anode bake plant.

DESCRIPTION OF PROCESS

All aluminum production in the United States is by electrolytic reduction of alumina (Al_2O_3). Alumina, itself an intermediate product, is produced from bauxite, a naturally occurring ore of hydrated oxides of aluminum. Major world sources of bauxite are South America and Australia.

Figure 1 presents a schematic flow sheet of the aluminum reduction process. Alumina is shipped to the primary reduction plant where it is electrically reduced to aluminum and oxygen. This reduction process is carried out in shallow rectangular cells (pots) made of carbon-lined steel with consumable carbon blocks which are suspended above and extend down into the pot (Figure 2). The pots and carbon blocks are connected electrically to serve as cathodes and anodes, respectively, for the electrolytical process. Cryolite, a double fluoride salt of sodium and aluminum (Na_3AlF_6), serves as both an electrolyte and a solvent for alumina. Alumina is added to and dissolves in the molten cryolite. The cells are heated and operated between 950° and 1,000°C with heat generated by the electrical resistance between the electrodes. During the reduction process, aluminum ions migrate to the cathode where they are reduced to aluminum. Because of its heavier weight, the aluminum remains as a molten metal layer underneath the cryolite. Oxygen ions migrate to and react with carbon in the anode to form carbon dioxide and carbon monoxide which continually evolve from the cell.

Alumina and cryolite are periodically added to the pot to replenish material which is removed or consumed during normal operation. Periodically, the molten aluminum is siphoned or "tapped" from beneath the cryolite bath

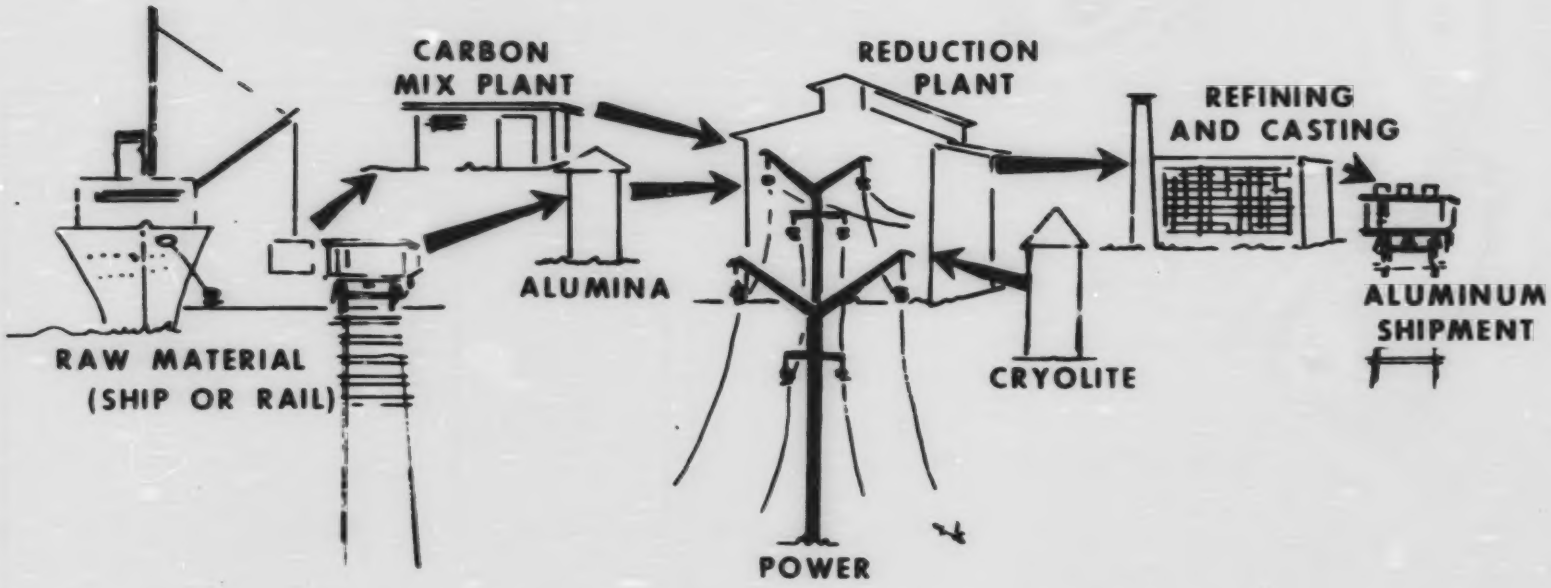


Figure 1. Aluminum reduction process.

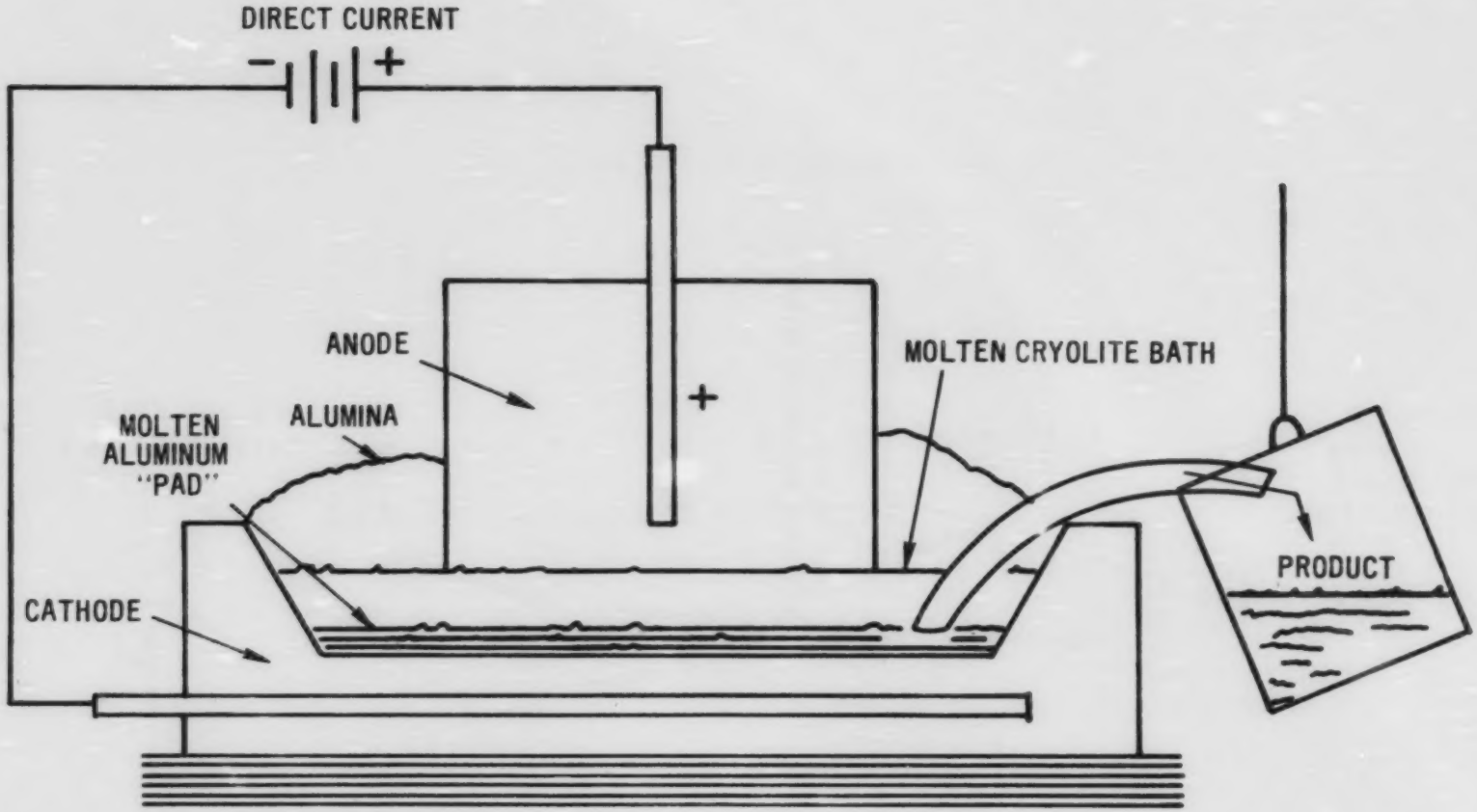


Figure 2. Aluminum reduction cell.

and moved to holding furnaces in the casting area. The product aluminum is held in the molten state until it is cast into billets to await further processing.

Three different types of cells are used for the production of aluminum: the vertical stud Soderberg (VSS), the horizontal stud Soderberg (HSS), and the prebake (PB). Schematic diagrams of these cells are shown in Figures 3, 4, and 5. These cells differ primarily in their physical configuration, to wit, the provisions for introducing the electrical current across the cryolite bath. Although they require more power, the Soderberg systems were acclaimed initially because they obviated the need for a separate facility to manufacture anodes. Soderberg cells permit the consumable anode to be baked in situ. A mixture of ground coke and coal tar pitch is periodically added to the top of the electrode. Heat from the process drives off the lower boiling organics and fuses the new material to the old electrode. Partially because of the problems with the volatile pitch which condenses in the duct-work and the control device, and partially because of the problems inherent in simultaneously controlling fluorides and organic emissions, any previous economic advantage of the Soderberg systems is diminishing and the trend appears to be toward the PB cell. As can be seen from Figures 3 and 4, the major difference between the two types of Soderberg cells insofar as the process is concerned is the manner in which the pins which carry the current are inserted into the anode.

The PB cell uses an anode that is precast. Since the anode is consumed during normal operation, old anode remnants or "butts" are replaced periodically with new anodes. The old remnants are removed from the cell,

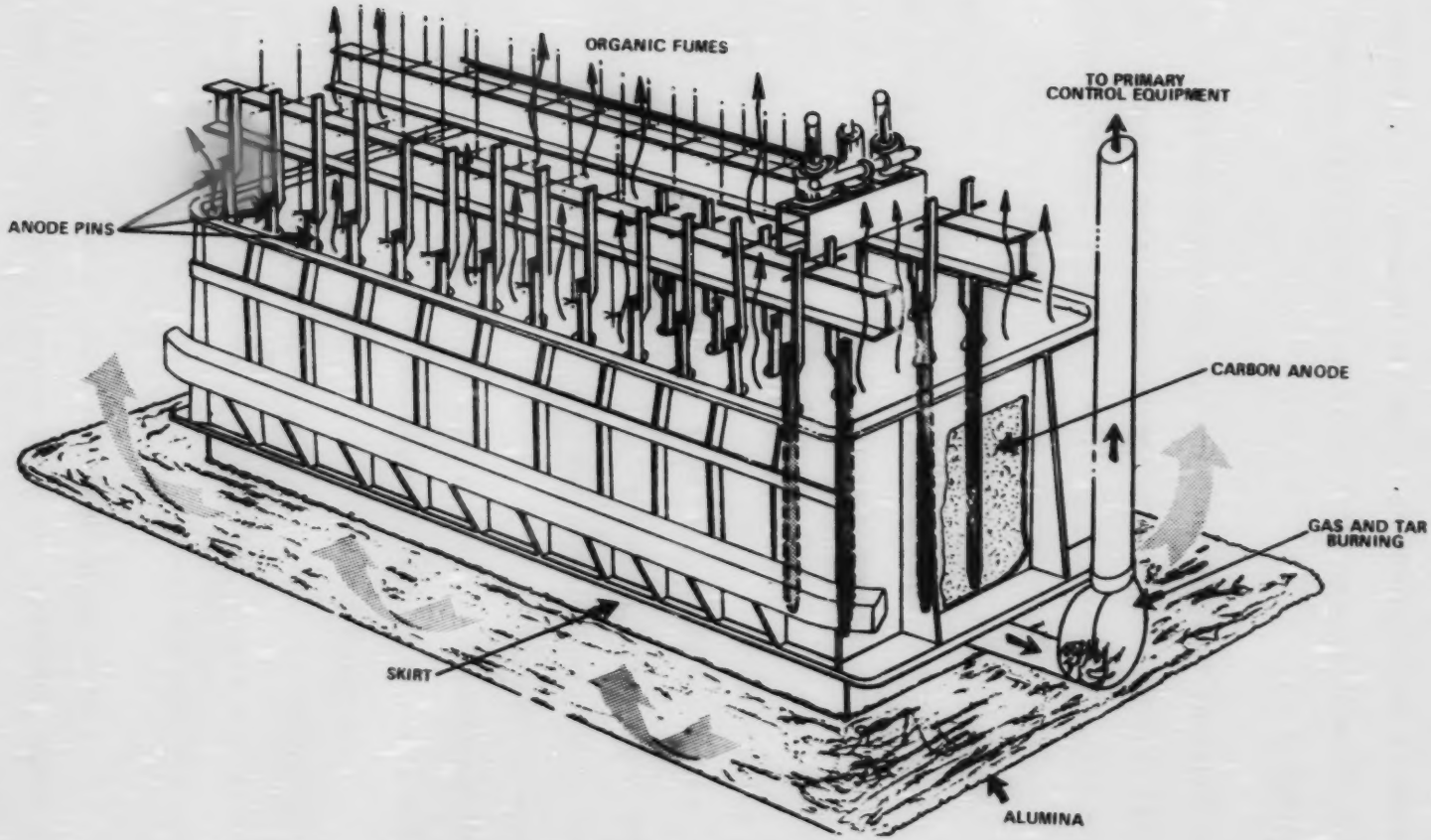


Figure 3. Typical vertical stud Soderberg Cell hooding.

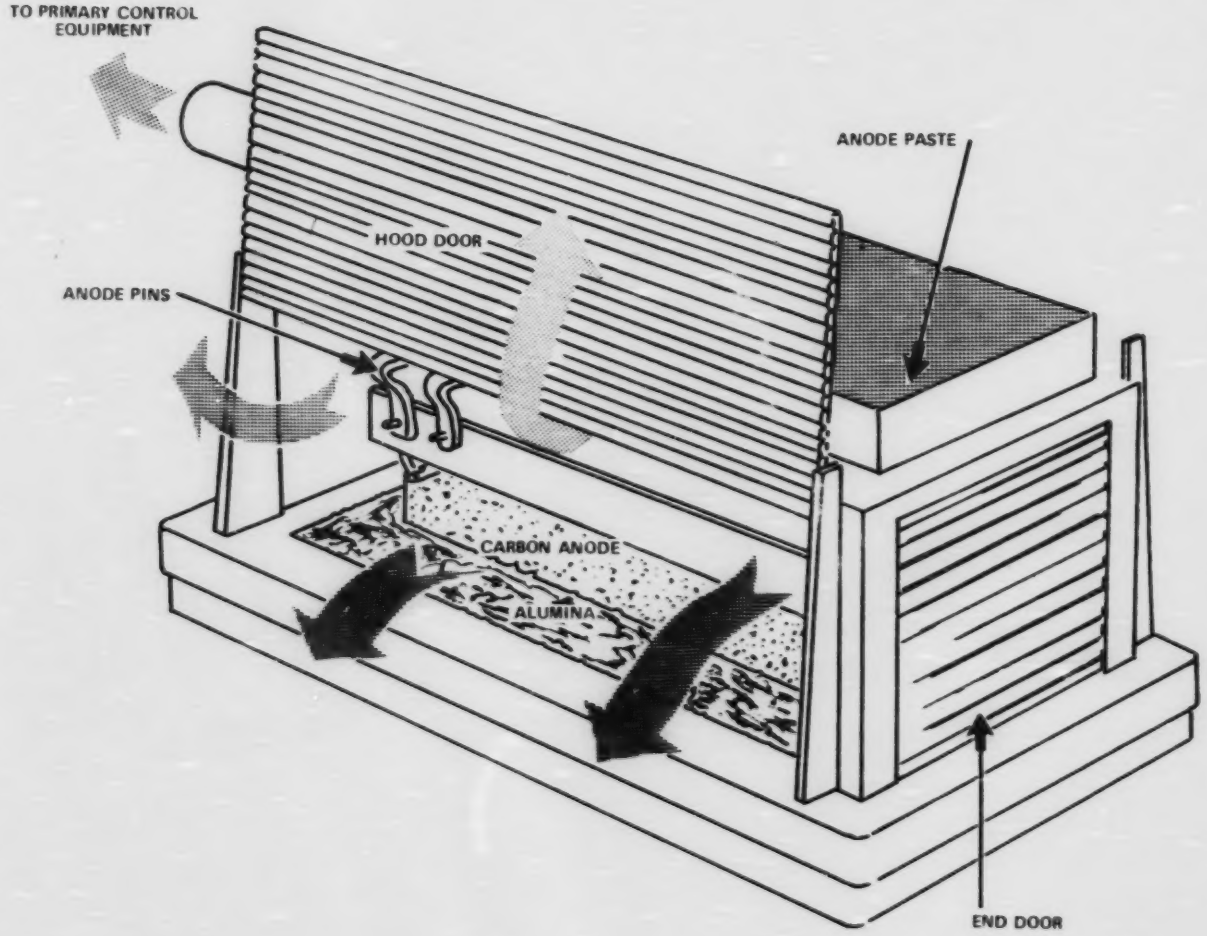


Figure 4. Typical horizontal stud Soderberg cell hooding.

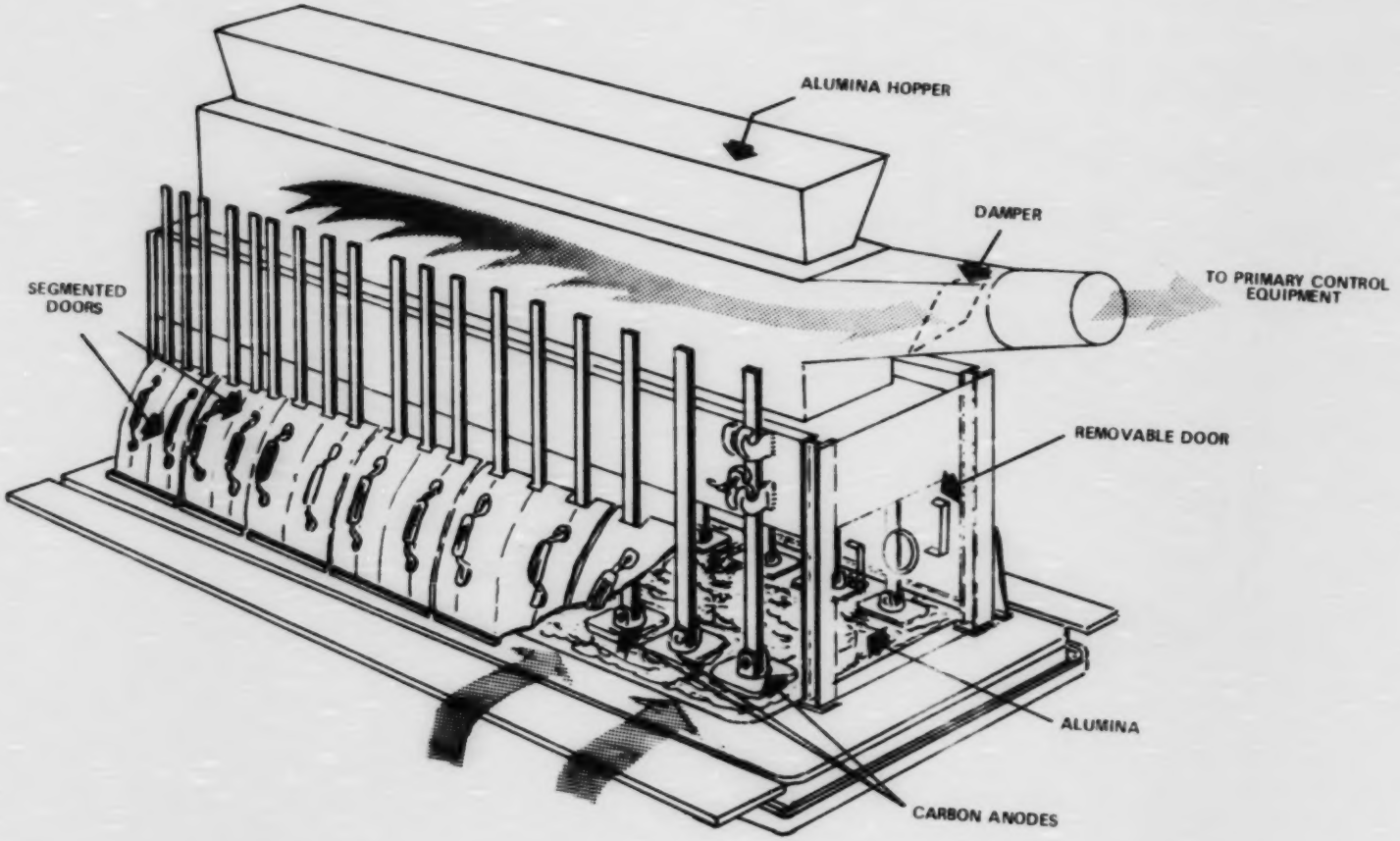


Figure 5. Typical prebake cell hooding

cleaned, ground, mixed with new coke, and blended together with coal tar pitch in an anode prebake plant. The mixture is weighed, then solidified by slowly baking in a furnace for about 30 days.

Although somewhat academic from the process aspect, the type of stud used has a major effect on fugitive emissions that escape the cell as we shall see later. This is partially because air volume through the hooding system varies between cell types, from 4,000 to 8,000 scfm on HSS and PB and from 400 to 600 on VSS.

EMISSIONS AND METHODS OF CONTROL

Several types of pollutants are emitted during the production of primary aluminum. The major emission source is the reduction cell. Another source is the anode baking facility.

An uncontrolled primary aluminum plant can emit 40 to 60 pounds of fluoride (F^-) per ton of aluminum produced.[1] A poorly controlled primary aluminum plant can release 15 pounds of F^- per ton of aluminum.[1] Such installations are likely to be equipped with inefficient capture systems (hoods) on the reduction cells and inefficient water scrubbers. A 600-ton-per day (TPD) plant so equipped would emit 9,000 pounds of F^- each day. Plant capacities in the United States range from 100 to 750 tons of aluminum per day.[1] In most primary aluminum plants, those emissions that escape the hoods (thereby escaping the primary control system) exit directly through the roof of the building to the atmosphere (Figure 6). Such "uncontrolled" secondary emissions can be several times as large as those which pass through the primary control system. An overall control efficiency of 95 to 97 percent

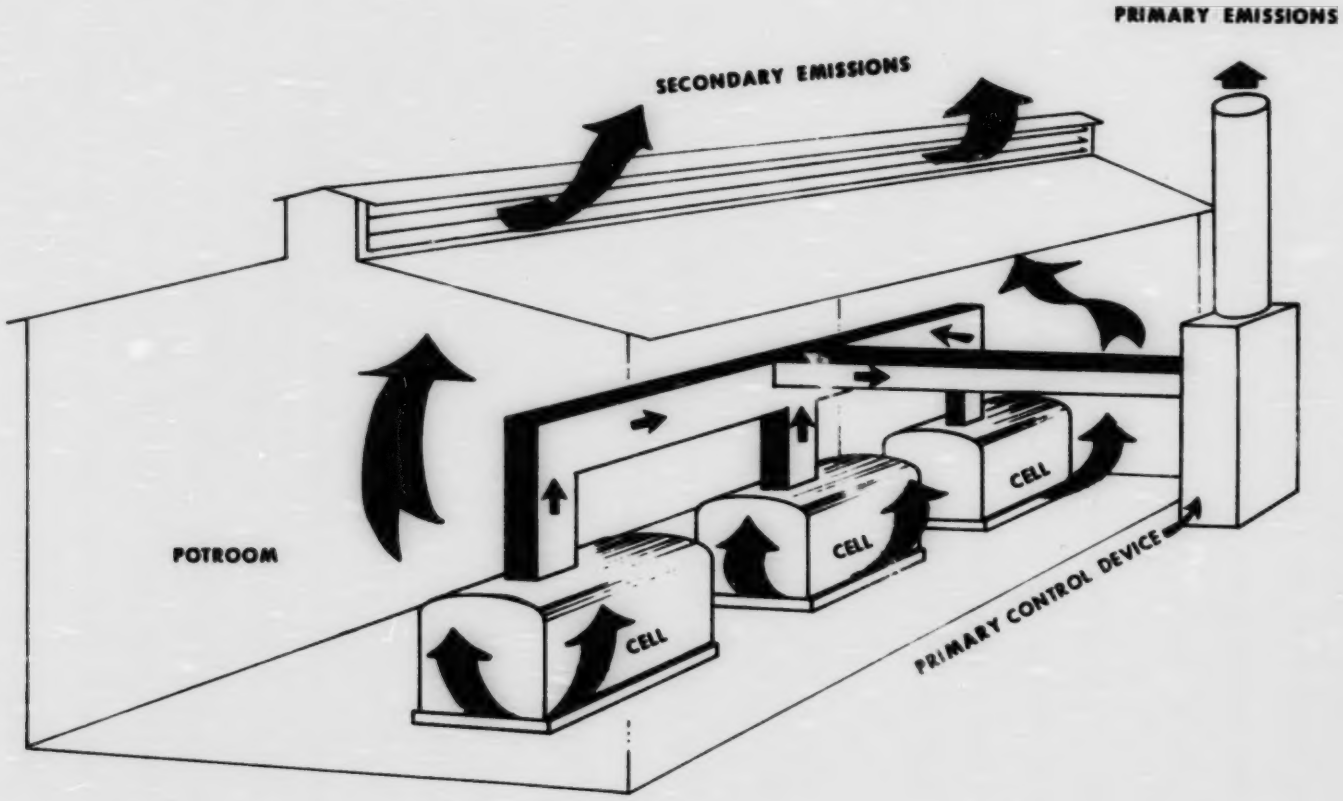


Figure 6. Potroom emissions.

of the fluorides generated in the potroom will be required to meet the proposed performance standard. The proposed standard for fluorides will also result in efficient control of both particulates and organics.

An uncontrolled plant can be a significant source of particulates by emitting 112 pounds of particulates per ton of aluminum produced or over 33 tons each day.[1] A poorly controlled plant may release as much as 40 pounds of particulates per ton of aluminum produced.[2] Such installations frequently attempt to control emissions with relatively inefficient water scrubbers. A 600-TPD plant so equipped would emit 12 tons of particulates each day. Particulates possibly originate in two ways: simple entrainment in the vent system during periodic additions of alumina and cryolite, and condensation of material vaporized from the molten bath and carbon anodes. It is estimated that 25 percent of the weight of particulates can be complex fluoride compounds such as cryolite (Na_3AlF_6), aluminum fluoride (AlF_3), calcium fluoride (CaF_2), and chiolite ($Na_5Al_3F_4$).[1] These can be divided into two categories: water soluble and water insoluble. (CaF_2 is the primary water-insoluble fluoride.) Measurements of particulate emissions and over 40 hours of visible emission readings recorded by EPA indicated that dry control systems or wet scrubbers in series with wet electrostatic precipitators provide the best control for particulates. These systems had opacity readings of 10 percent or less at all times.

The high temperature of the cell causes emissions of organics (tar-fog) from the anodes at the cells. This fume is not effectively controlled by water scrubbers and forms the bluish haze characteristic of aluminum plants. This haze is quite visible from HSS and VSS cells. (Although most of these fumes

are sometimes burned at VSS cells, the burners are not always maintained in proper operating condition.) The PB has the least visible organic fume because the low-boiling organics have already been driven off during the baking process at the anode bake plant. Both dry control systems and wet electrostatic precipitators appear to provide good control of organic fumes.

It has been reported that large amounts of carbon monoxide (CO) are generated at the reduction cell.[1] Measurements by EPA show roughly less than 1 percent by volume in the exit gas streams. Some combustion to carbon dioxide (CO_2) occurs when the hot CO gases contact air.

SO_2 emissions are the product of sulfur contamination in the organics from which the anodes are formed. Anode bake plants emitted from 5 to 47 parts per million (ppm) and VSS and HSS plants, up to 80 ppm based on limited EPA tests. (One source reports up to 200 ppm SO_2 can be emitted.[3]) The sulfur content of the coke now ranges from 2.5 to 5.0 percent,[1] equivalent to SO_2 emissions of 7 to 14 tons each day from a 600-TPD plant.

Results of a limited number of samples indicate NO_x emissions from primary aluminum plants are very low, about 5 ppm.

Fugitive dust and visible emissions from ancillary operations such as production of anodes and handling of raw materials can be controlled by installation of suitable control devices. Historically, cyclones, baghouses, and pneumatic handling systems have been justified based on the value of recovered materials.

Several State and local regulations limit fluoride emissions from primary aluminum plants. Some base the restrictions on production rate, others on the ambient air concentration of fluoride or its concentration in surrounding vegetation. The most stringent State regulation has dual limits of an annual average of 1.00 pound of total fluoride per ton of aluminum produced and a monthly average of 1.3 pounds (the monthly average is based on the average of three emission measurements which are required per month). This regulation was developed from emission data collected in early 1973 at one prebake plant that combined a new dry primary control system with an existing wet secondary control system. Although the sampling and analytical techniques used are not known, EPA's Method 13 was not used, so results and standards are not directly comparable. Also it should be recognized that a standard based upon averaging over relatively long periods is less stringent than a numerically equivalent standard established as a nonexceedable limit.

Unquestionably, emissions as low as required by this State standard may be achievable. An examination of the available fluoride emissions from primary aluminum plants show that about 75 percent of the allowable emissions will exit from the roof without being exposed to any control device. Certainly the installation of even a poor secondary control device could reduce the total emissions. However, it is the Administrator's judgment that the overall Federal standard of 2.0 pounds for the potroom will indeed require the best demonstrated technology, considering cost, within the intent of the Clean Air Act.

RATIONALE FOR PROPOSED STANDARDS

Selection of Pollutants for Control

Information gained from the study by EPA titled, "Air Pollution Control in the Primary Aluminum Industry," (EPA No. 450/3-73-004 A&B and PB-224-282/AS) indicated that fluorides and particulates are the principal pollutants from primary aluminum plants. During this investigation, some information was also collected on emissions of sulfur oxides, nitrogen oxides, and carbon monoxide. A standard for control of sulfur oxides is not now being considered because control technology has not been demonstrated in this industry. Primary aluminum reduction plants could become a significant source of SO_2 emissions partially because of a trend toward the use of higher sulfur raw materials for the manufacture of anodes. Nitrogen oxide emissions were found to be insignificant. The available data on carbon monoxide emissions indicated that these emissions were also insignificant.

Documented evidence has shown that fluorides emitted by industrial plants are responsible for damage to commercially grown flowers, fruits, and vegetables. Fluorides in low concentrations can also be absorbed by grasses and plants. They can then cause fluorosis in animals that feed upon such forage. This disease distorts bone development, retards growth, mottles teeth and adversely affects general health.[4,5,6,7] For these reasons, fluorides were selected for control. Subsequent source tests have shown that if fluorides are well-controlled, the resulting control of particulates and organics will also be good.

Selection of Units for the Standard

Although both concentration and mass units were considered for the standard, mass units of pounds of total fluorides (versus water-soluble or gaseous fluorides) per ton of aluminum produced are recommended for the following reasons:

1. Sampling techniques which permit segregation of particulate and gaseous fluorides have not been standardized and are not widely accepted.

2. Sampling techniques for water-soluble fluorides have also been suspect on occasion. Some accepted insoluble fluoride compounds may convert to a soluble form in the sampling train if the samples are held too long before analysis.

3. To control the emission of total fluorides, the source must control both particulate and gaseous fluorides. The standard thus indirectly controls particulate emissions.

4. A standard based on concentration units would be inconsistent because of variations in the volume of ventilation air used by various plants and the large fluctuations within a single plant.

5. Aluminum production rates are relatively steady.

6. Product aluminum is weighed as it is removed from the potline; therefore, accurate production rates are available.

Selection of Sampling and Analytical Techniques

Where possible, sampling and analytical procedures were used which conformed to Methods 5, 6, and 7, determination of particulate, sulfur dioxide, and

nitrogen dioxide emissions from stationary sources, respectively (described in the Appendix to the December 23, 1971, Federal Register, Volume 36, Number 247). Measurements of oxygen (O_2), carbon dioxide (CO_2), and carbon monoxide (CO) were conducted with an Orsat analyzer.

Samples of emissions from primary control systems for fluoride analysis were collected isokinetically with the sampling train described in Method 5 and traversed in accordance with Method 1, "Sample and Velocity Traverses for Stationary Sources."

Standard methods for measurement of fluoride emissions were not available in the aluminum industry when EPA began its emission test program. EPA determined that the basic sampling train used with EPA Method 5 could be used to collect samples of fluoride emissions. Several minor modifications of the train were tried during the initial tests. At the same time, a similar program of fluoride measurement was being conducted by EPA in the fertilizer industry. EPA's Method 13 was developed from the experience gained in these measurement programs. Although basically the same as Method 5, Method 13 incorporates some options or variations to improve sampling for fluorides, whereas Method 5 is designed for particulate sampling. Results of the earlier tests, although not sampled in strict accordance with Method 13 as it finally developed, are comparable.

The analytical method recommended for analysis of samples for fluoride is the SPADNS Zirconium Lake Method. It was chosen after several analytical methods were studied by EPA. It has proven accurate and reliable for years by governmental and industry sources. Samples from EPA's emission test program were analyzed by this or comparable methods.

When emission samples upstream and downstream of a control device could not be taken simultaneously, sequential sampling was accomplished as quickly as possible. Length of sampling times varied from 2 to 24 hours.

Special sampling techniques were required to measure emissions of exit gases where we could neither traverse nor sample isokinetically. These special sampling techniques were used to sample secondary emissions from roofs or monitors. Some plants utilized a control system to reduce these emissions, others did not. Traverse sampling was not practical because of the unusual configuration of the area to be covered. Also, isokinetic sampling was compromised to maximize the collection efficiency of the pollutant (fluoride) in the impinger section of the EPA train. Isokinetic sampling would substantially reduce the impinger collection efficiency because of low gas velocities at the sampling location.

Before selecting a method, the Agency held discussions with each company on its sampling techniques for secondary emissions. As a result, sampling at a constant rate was selected. In addition, since the gas velocity was low and reasonably constant, a single point in the gas stream was sampled. This single-point method is not unreasonable since about 70 percent of the particulates are below 5 microns in diameter and behave almost like a gas.[4] (Some data indicate that up to 60 percent of particulates released at the cell could be less than 3 microns in size.)[1] A very important criterion was to ensure the sample rate permitted maximum efficiency of the impinger section of the sampling train. The samples were collected at a rate of 1 cubic foot per minute (ft^3/min) close to the center of the discharge of the gas stream to minimize ductwork or other interferences. The sampling points for secondary

systems were usually above the cells controlled by the primary control system. When possible, the primary and secondary systems were sampled simultaneously. Gas flows from the building were either measured by the company with EPA observing or the average gas flows provided by the company were used.

A second and more elaborate method of sampling emissions from the monitor was provided by one company who uses this system at several of their plants. Continuous samples from a multipoint sampling system in the roof monitor (Figure 7) were drawn through intake nozzles to a common manifold and discharged through a stack. Velocity into the nozzles corresponded to the 24-hour average velocity through the monitor. Isokinetic sampling was then performed at the stack to determine the concentration of total fluorides. Gas flow through the roof monitor was simultaneously measured at many points with anemometers. These anemometers, spaced in the monitor area, were connected to a computer which provided a gas velocity reading every few minutes. This reading permitted a gross measurement of gas flow during the sampling period. The company has provided data which indicate excellent correlation between this sampling method and elaborate manual techniques required for sampling the monitors. Certainly, results of this type of test on a secondary system should be more representative than those from the single point sample.

Samples were analyzed for both water-soluble and water-insoluble fluorides. The water-soluble fluorides were determined by the SPADNS Zirconium Lake Method 12, after the sample was first distilled with sulfuric acid. Water insoluble fluorides were determined by the SPADNS method after the sample had been fused with NaOH. These are both standard fluoride analytical techniques used for many years by industrial and governmental laboratories.

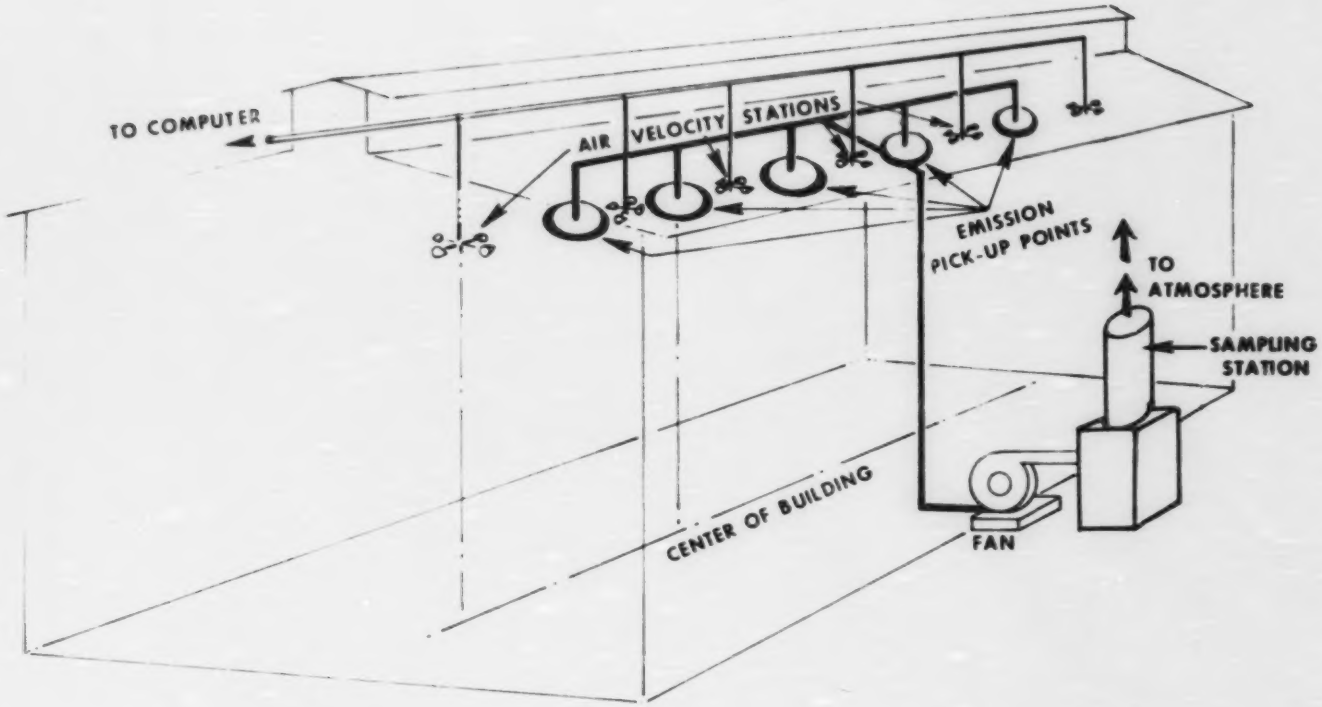


Figure 7. Monitor pick-up system.

Discussion

A. Determination of Affected Facilities

Information initially available for use in the development of standards of performance for the primary aluminum industry resulted from a study by EPA.[1] The study had been in process for over a year prior to initiation of the program to develop standards of performance and was primarily concerned with emissions and control techniques of the United States primary aluminum industry. It utilized a survey of the industry by questionnaire, a literature search, and measurements of emissions from select primary aluminum plants. The study provided information concerning the history, trends, industrial statistics, processes, emissions, economics, and emission control technology and procedures of the primary aluminum industry.

After reviewing this work, EPA consulted representatives of several State agencies and manufacturers of control equipment. Assimilation of all information confirmed that the reduction cell and anode prebake furnace are the major sources of pollution at primary aluminum plants, and that the primary pollutants are fluorides and particulates.

Efficient removal of fluoride from a gas stream is relatively easy. Unfortunately, a significant portion of the gaseous emissions from a cell can escape capture by the hoods. These fluoride-bearing gases then bypass the primary collection system. To properly determine the total emissions from a primary aluminum plant, emissions must be measured as they exit both the building (or potroom) and the control device. Consequently, it was not possible to use the cell as an affected facility, and the entire building had to be so designated.

All emissions from the anode bake plant exit through the control device so the entire plant was selected as a second affected facility. Figure 8 presents a schematic of the two affected facilities.

B. Determination of Best Control Techniques for Aluminum Production

A discussion of best control for potrooms of primary aluminum plants must consider the two routes by which emissions exhaust to the atmosphere: those captured by the hood which subsequently pass through the primary control device (which we will refer to as "primary emissions") and those which elude the hood system and exit the building through the roof monitors ("secondary" emissions). Most plants do not utilize a control device to reduce secondary emissions.

Table 1 affirms the importance to both wet and dry types of primary collection devices of good capture of emissions by the primary hood collection system. Notice the average fluoride removal efficiency of all primary control devices was 99.5 percent. Not unexpected is the much lower efficiency of the low-energy spray-screen scrubbers sometimes used to control secondary emissions. Collectively, the two averaged only 76.6 percent removal efficiency.

It is obvious that the "best demonstrated control" of fluorides is heavily, if not totally, dependent on use of a hood which is highly efficient at capturing fluoride emissions and directing them to the primary control device rather than permitting them to escape and be scrubbed by the much less efficient secondary system.

As mentioned in "Description of the Process," the physical characteristics of each of the three types of cells place various limitations on the design of the hooding for the primary collection device. At one extreme is the

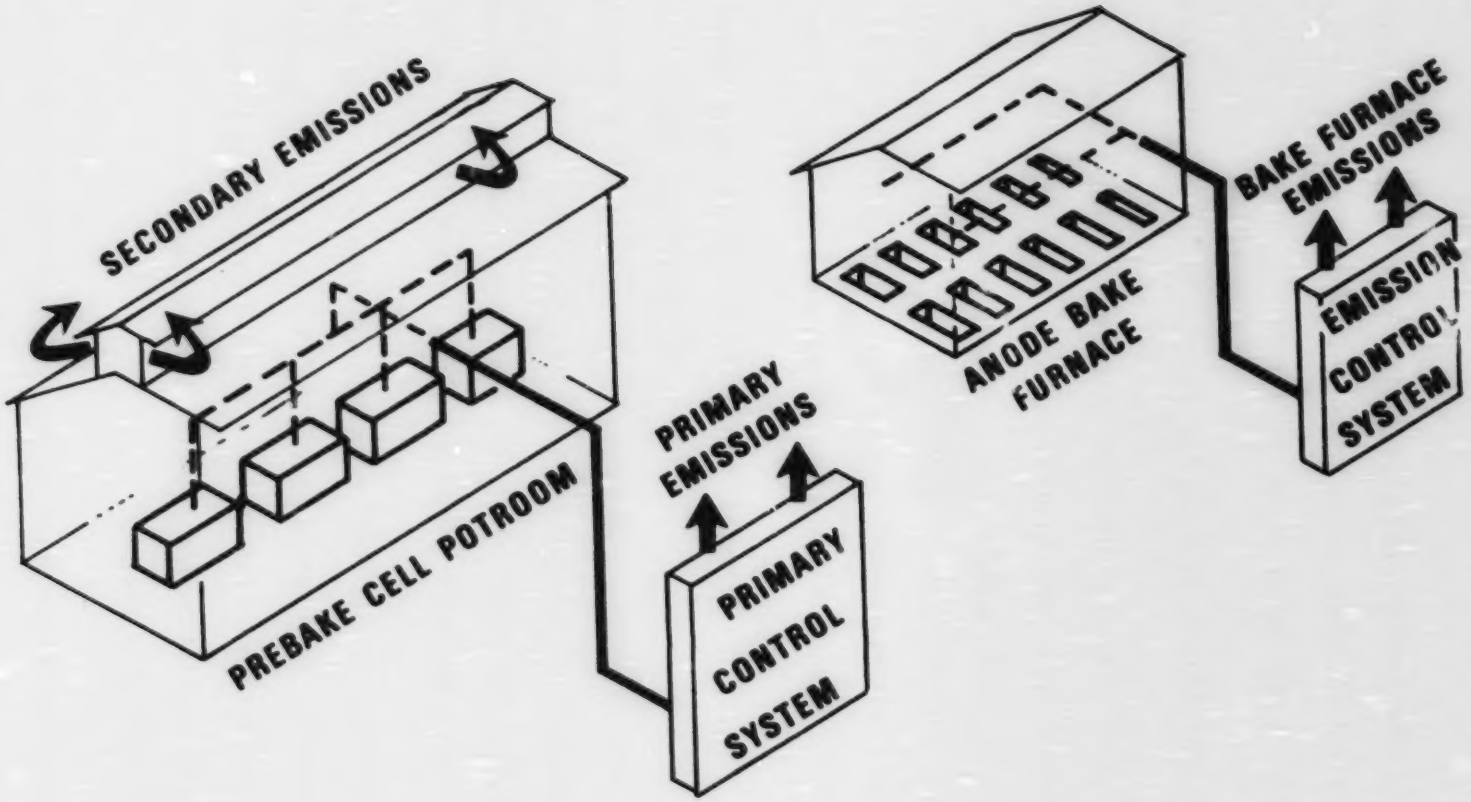


Figure 8. Prebake plant with anode bake furnace.

TABLE 1. PRIMARY ALUMINUM REDUCTION INDUSTRY

	PLANT	CELL TYPE	TYPE OF CONTROL	FLUORIDE EMISSIONS, LB TF/TAP*		EFFICIENCY PERCENT
				INLET	OUTLET	
PRIMARY	A	PB	FLUID BED	48.05	0.14	99.70
	B	PB	FLUID BED	61.42	0.49	99.30
	C	HSS	SCRUBBER PRECIPITATOR	46.60	0.40	99.10
	D	VSS	SCRUBBER PRECIPITATOR	36.43	0.013	99.97
	D_1	VSS	SCRUBBER PRECIPITATOR	36.43	0.024	99.30
	E	VSS	FLUID BED	36.06	0.04	99.89
	AVERAGE A, B, C, C, D_1, & E					99.53
SECONDARY	D	VSS	SPRAY SCREEN	2.85	0.76	73.3
	E	VSS	SPRAY TOWER	11.20	2.60	76.0
	AVERAGE D & E					74.6

*POUND(S) TOTAL FLUORIDE PER TON OF ALUMINUM PRODUCED.

VSS cell. Since a substantial area of the surface of the molten bath is outside of the skirt of the hood (Figure 3), the capture efficiency of the hood for this area is poor. Fortunately, the molten surface is usually covered by a crust of cryolite and regularly replenished with a layer of alumina. The latter will adsorb fluorides that otherwise would escape. However, periodically areas of the molten bath are exposed, such as immediately after the crust is broken to permit addition of alumina. Because these breaks are outside of the hood, much of the subsequent emissions escape unattended to the secondary system. Although the length of time between breaking the crust and the addition of new alumina is largely a function of operating procedure, it can be as long as half an hour. This delay could be significantly reduced by training and closer supervision.

The PB and HSS cells can be completely hooded as shown in Figures 4 and 5. The collection efficiencies of such hoods have been estimated at 97 to 99 percent. Still higher capture efficiencies have been elusive because the hoods must be opened on a scheduled basis to perform various "cell work," such as pin or anode changes, raw material additions, crust breaking, tapping, and any other operation that requires access to the interior of the cell.

Some companies in the industry have recognized the advantages of containing fluoride emissions in a primary system rather than attempting to install or improve the collection efficiency of a secondary system. They have made changes which significantly affect total emissions.

Historically, the doors on HSS hoods extend the full length of both sides of the cell (15 to 36 feet). As a result, when the operator opens the door of the cell, he exposes a side the complete length of the cell.

Most emission control systems are inadequate to provide sufficient draft to capture all the emissions under these circumstances. A PB hood can be segmented so that the area of the cell exposed during working can be minimized and capture gas velocity maintained proportionately higher. Also one company using the prebake process has alleviated the draft problem somewhat by using throttling valves in the ductwork of all cells so that the capture gas velocity can be doubled before one or more of the segmented doors are opened. These methods of improving capture are resulting in fewer overall emissions. Modern plants are assisting air pollution control by closely controlling the process variables of temperature, chemistry, voltage, alumina and cryolite additions, and automatic crust breaking without opening the hood.

Companies have also become more aware of the effect of poor maintenance of cells and hoods on emissions. As equipment ages, hoods and doors are bent, broken, misplaced, and even partially melted. The increase in open area can render a marginal draft system completely ineffectual.

After the emissions are captured by the primary system, control is not difficult. Plants may achieve good control with either of two systems. "Dry" systems, which sometimes incorporate cyclones upstream of the control device, take advantage of the strong affinity of alumina for fluoride. Figure 9 shows two types of dry systems. After the effluent passes through it, the alumina is fed to the cells, thereby providing a closed-loop recycle for fluorides. Dry control systems have been developed for all three types of cell. Well-controlled "wet" primary systems, such as shown in Figure 10, utilize a high-efficiency wet scrubber followed by a wet electrostatic precipitator. These too can be used on all three types of cell.

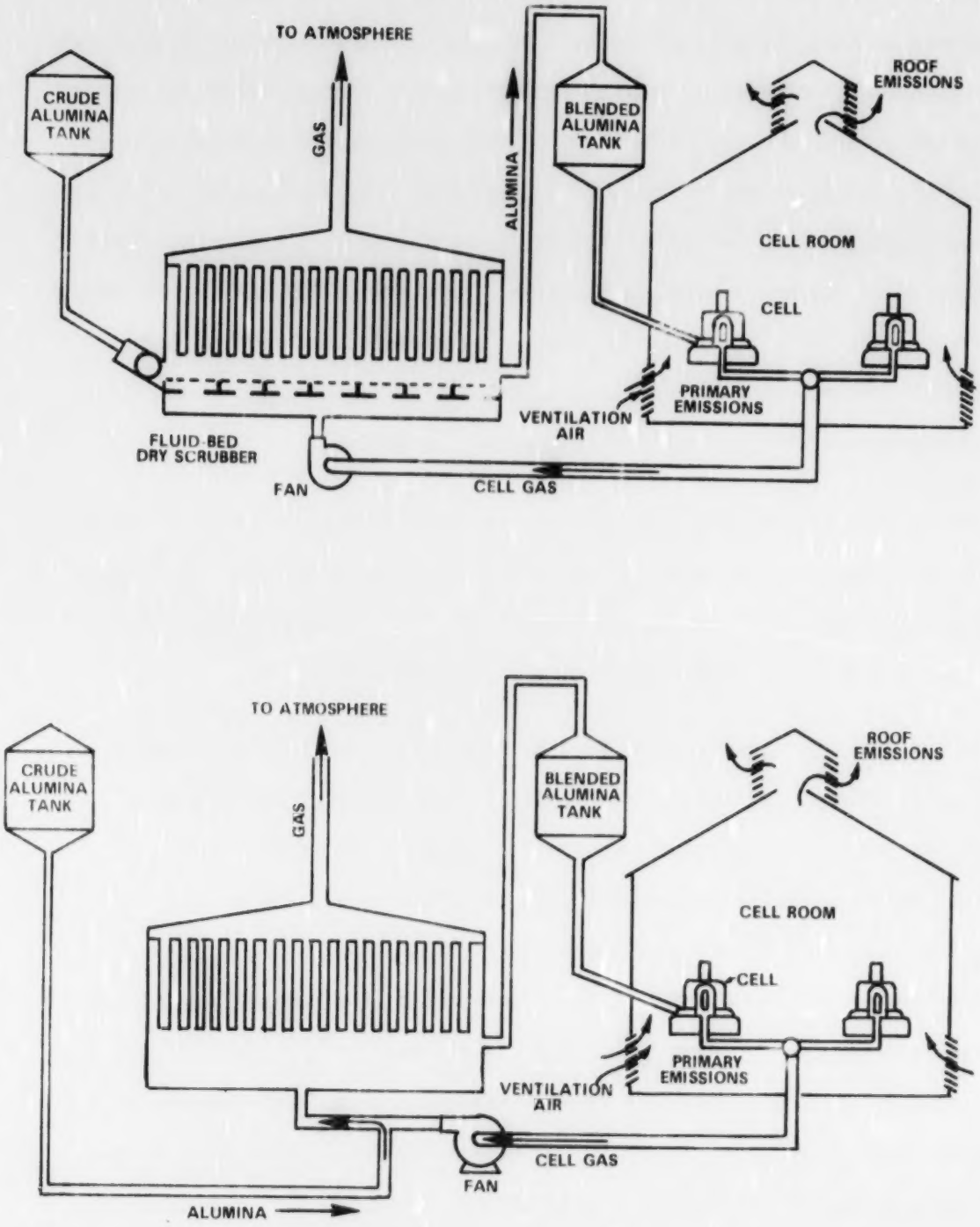


Figure 9. Fluid-bed dry scrubber (top); injected alumina dry scrubber (bottom).

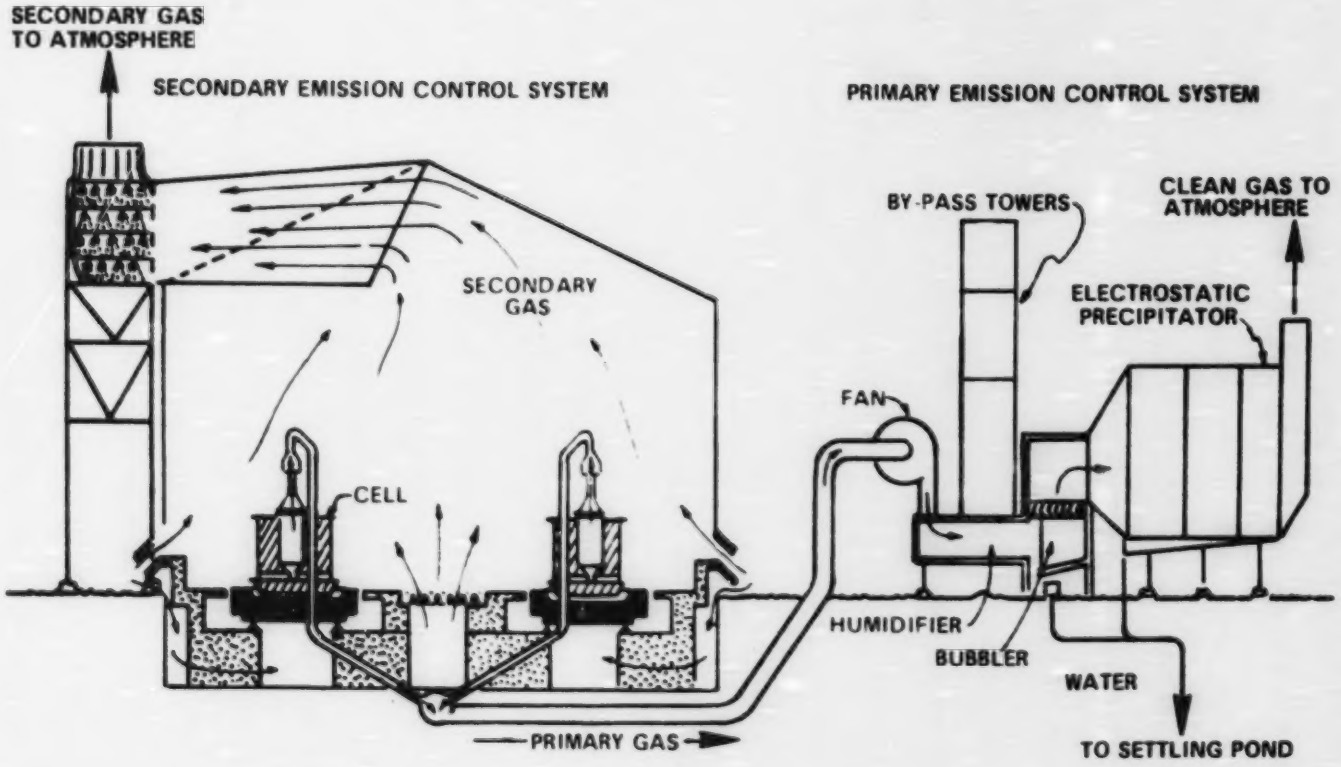


Figure 10. Flow diagram for primary and secondary emission control systems.

Those emissions that elude the primary collector are much more likely to escape to the atmosphere. Potrooms, which house the cells, are designed to encourage convection currents of ventilation air to sweep the building. This is accomplished by constructing openings in the floor or by providing louvers along the lower walls of the potroom or both. As a result, secondary emissions are diluted by the 30,000 to 60,000 cubic feet of ventilation air per cell which passes through the roof monitor each minute. Strong cross-winds can even carry emissions through the floor or wall openings, causing them to bypass the secondary control system. One operator of a new VSS cell plant has minimized this problem by closing the sides of the potroom and using forced ventilation. Forced ventilation will minimize the effect of outside weather conditions, yet provide for the health, safety, and comfort of operating personnel.

C. Data Base - Primary Emissions

Preliminary investigations revealed the locations of several reportedly well-controlled plants. Eight were visited and information was obtained on the process and control equipment. Six plants were selected to be tested; these included all three types of reduction cells and both wet and dry air pollution control systems. The other two plants had no stacks suitable for source measurements. Two of the six plants tested were later retested a second time to confirm or supplement previous data. Inspections of two primary aluminum reduction plants in Europe, one a PB, the other a VSS, revealed their primary control systems are comparable to those in the best-controlled plants in the United States. Both plants use dry control systems. More recently, data were submitted to EPA on a PB plant in the United States using a dry primary control system and a wet secondary control system.

Figure 11 presents the results of all measurements of emissions from primary control systems. One of the first plants sampled by EPA as part of the original study was Plant A, a VSS plant. This original test indicated emissions of 1.0 to 1.4 pounds of total fluoride per ton of aluminum produced (lb TF/TAP). The company extensively modified its control system by adding a wet electrostatic precipitator downstream of the "bubbler" scrubber. Three measurements reveal emissions averaged 0.012 lb TF/TAP after the modification (A_1). More recently, three measurements by EPA on this same control system averaged 0.016 lb TF/TAP (A_2). One difference between the second and third series of measurements conducted at this plant was an increase in sampling time from about 6 to 24 hours per measurement to confirm this factor did not affect the data.

Data submitted by the company to a State agency on total emissions of fluoride averaged about 0.024 lb TF/TAP (A_3). Maximum emissions from the primary system were 0.039 lb TF/TAP.[9] Calculations based on analysis of inlet concentrations at Plant A indicate the primary control system is 99.9 percent efficient and the secondary control system is about 73 percent. Reduced efficiency is the common shortcoming of low energy wet secondary systems on a low concentration gas stream.

The average of three measurements by EPA of a primary control system on an HSS plant reveal emissions from a scrubber in series with a wet electrostatic precipitator averaged 0.41 lb TF/TAP (B). Information provided by the company indicates an average of 0.50 lb TF/TAP (B_1) for the primary control system.[2]

Results of four measurements by EPA of a primary control system show emissions from a PB plant which uses a fluid-bed dry scrubber averaged 0.15 lb TF/TAP (C).

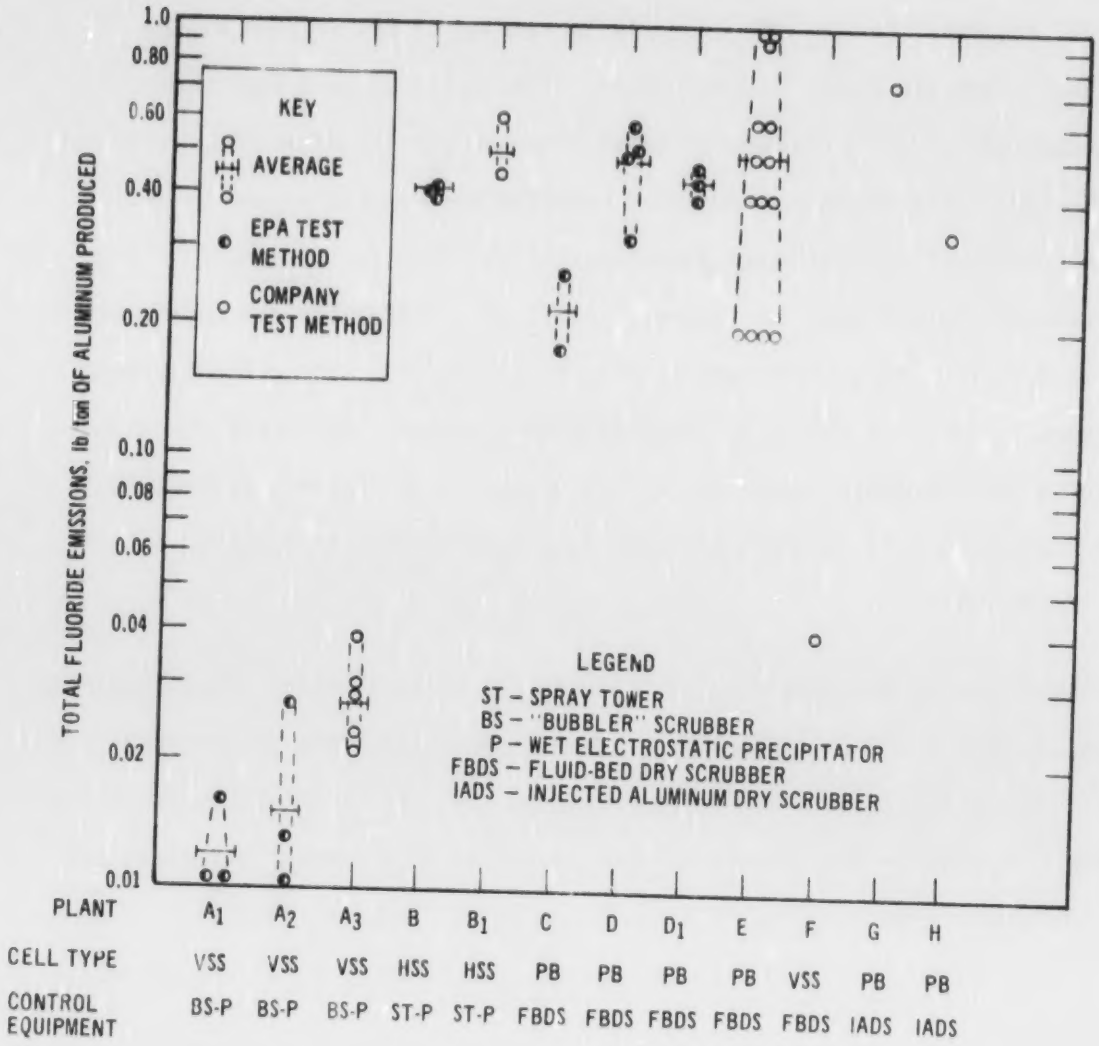


Figure 11. Primary emissions from the primary aluminum reduction industry.

Results of six measurements by EPA of a primary control system indicate emissions from another PB plant with a fluid-bed dry scrubber averaged 0.87 lb TF/TAP (D). Although measurements ranged from 0.26 to 1.70 lb TF/TAP, two high measurements of 1.70 lb are suspect. They are not representative based on both the company's normal operating parameters and results of their own measurements. Furthermore, these two measurements were obtained during two long runs on the same day. During the last of the two, the operator identified and corrected a malfunction in the control device.

The other four measurements shown for Plant D represent tests before and after the malfunction and indicate average emissions of 0.49 lb TF/TAP. Three additional measurements (D_1) on another day showed average emissions of 0.44 lb TF/TAP. Fourteen data points provided by the company which owns Plants C and D, for a 1 year period, indicate emissions from primary fluid-bed dry scrubbers averaged 0.51 lb TF/TAP. These are represented by (E) in Figure 11.[2]

This company, which also manufactures the control device, published a paper in The Journal of the Air Pollution Control Association, Volume 21, No. 8, August 1971, which shows emissions from three PB plants which use dry control systems. These data, which show total fluoride emissions, are presented here as Table 2. Company officials indicate that the high figures in Table 2 are now rare due to improved operating experience gained in the more than 2 years since this data was published.

Data presented to a State agency in 1973 by one PB plant, indicate emissions from a primary injected dry control system over a 6-month period averaged 0.31 lb TF/TAP (H).[9]

TABLE 2. TOTAL FLUORIDE EMISSIONS FROM A FLUID BED DRY SCRUBBER

	PRIMARY EMISSIONS, LB TF/TAP	SECONDARY EMISSIONS, LB TF/TAP	TOTAL AVG. LB TF/TAP
PLANT 1			
AVERAGE	0.36	1.48	1.84
RANGE	0.09 - 1.03	0.55 - 2.56	
PLANT 2			
AVERAGE	0.37	1.76	2.13
RANGE	0.02 - 3.96	0.55 - 2.95	
PLANT 3			
AVERAGE	0.75	0.97	1.72
RANGE	0.05 - 3.96	0.68 - 1.20	

One plant in Europe which uses VSS cells reported emissions of 0.04 lb TF/TAP (F) from a dry primary control system. Another European plant which uses PB cells and a dry primary control system reports average emissions as 0.74 lb TF/TAP (G).

From the summary information presented in Figure 11 and Table 2, it is obvious that a primary control system can achieve levels of control of 0.5 lb TF/TAP or less. The high values shown were resolved by one operator who added a wet precipitator to modify the control system. Another discovered an upset in the control device which was immediately resolved.

Sampling techniques used by companies furnishing other data were not known but it is assumed that a sampling technique relatively common to the industry was used.

D. Data Base - Secondary Emissions

Results of all available measurements of secondary emissions are presented in Figure 12. Measurements taken from the discharge of a spray-screen scrubbing device indicate emissions averaged 1.65 lb TF/TAP (A), 0.80 lb TF/TAP (A_1) and 2.02 lb TF/TAP (A_2). This is especially significant when you remember that primary emissions from the plant average only 0.02-0.03 lb TF/TAP after modifications (A_1 and A_2). The operator of this plant has submitted information to the State agency which showed secondary emissions averaged 1.37 lb TF/TAP (A_3), and to EPA which showed the average of 32 tests over a longer period as 1.52 lb TF/TAP (A_4).

Plant B presents the results of four measurements taken by EPA at the roof monitor of a plant which has no secondary control device. Emissions averaged

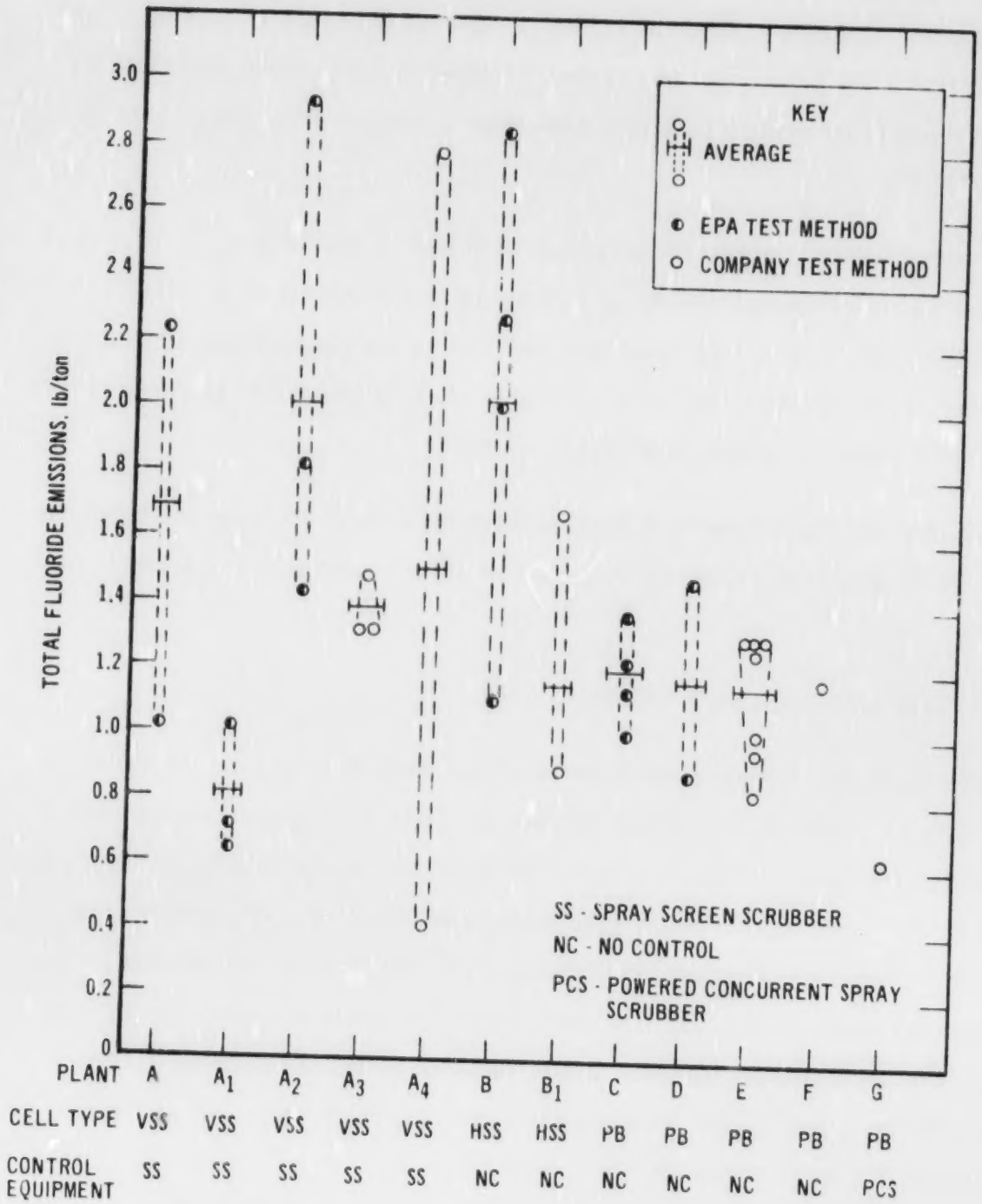


Figure 12. Secondary emissions from the primary aluminum industry.

2.10 lb TF/TAP (B). The company provided data to the State agency which revealed secondary emissions from all the potrooms to average 1.73 lb TF/TAP.[9]

The figures for secondary emissions merit some discussion because they vary so much. One, if not the most significant, variable which affects the emissions through the monitor is the capture efficiency of the hood. The potroom, which EPA sampled, was one of the plant's newest and contained the latest in hooded cells. Secondary emissions from this building as measured by the operator ranged from 0.91 to 1.68 lb TF/TAP with an average of 1.15 lb TF/TAP (B_1).[2] The differences between results of tests by EPA and the operator do not seem unreasonable. The operator's data were obtained by simultaneous 24-hour measurements at several points over many months.

In contrast, only one point in the monitor was measured by EPA. Furthermore, all measurements, except one, were conducted during the day: 12 to 13 hours for three measurements and 8 hours for one measurement. This single sample point is assumed to represent the total emissions from the 14 cells controlled by the primary control system. Realistically, however, these secondary emissions through the monitor are also affected by the adjacent cells, especially the other 14 cells on the other side of the building which share the same monitor area. Other causes for variation result from working the cells. Hood doors do not need to be opened for long periods for this purpose, but other activities may require longer exposure of the cell bed. Records kept by EPA and the operator of all activities to the 28 cells during the sampling periods reveal:

1. The lowest emission rate was indicated by a 13-hour sampling from Saturday afternoon to Sunday morning when the cells are relatively unattended.

2. The highest emission rate was indicated by an 8-hour measurement from early morning to afternoon during a weekday when activities for all cells are at their peak. In fact, there were pin changing operations directly below the sampling point which take considerable time.

It seems reasonable to conclude that:

If multipoint 24-hour sampling were performed, the extremes obtained during EPA tests should be dampened and more in line with the operator's results.

The results of four measurements of secondary emissions from a PB plant which has no secondary control device averaged 1.26 lb TF/TAP (C). The company indicated the cell hooding in this potroom was not their best compared to another plant within the company. Measurements of this secondary system were taken only to provide companion data to the primary system. The operator's best primary control device is connected to these hoods.

The result of two measurements of uncontrolled secondary emissions from another PB plant averaged 1.20 lb TF/TAP (D).

The data for $(E)^2$ represent results of emission measurements from an uncontrolled secondary system and were provided by the PB plant operator. A high value of 4.4 lb TF/TAP has been deleted from consideration because the primary collection system or process was not operating properly, also, this value is not statistically supported by the other measurements. The average emission rate without the 4.4 value is 1.14 lb TF/TAP.

One European operator reports emission rates from uncontrolled roof monitors as 1.18 lb TF/TAP $(F)^{10}$ based on samples taken during 18 months of continuous operation.

Data presented to a State agency in 1973 by one PB plant indicate emissions from a wet secondary control system over a period of 6 months averaged 0.66 lb TF/TAP (G).[9]

Although examination of Figure 12 would indicate measurements of secondary emissions ranged from 0.4 to 2.9 lb TF/TAP, more explanation is essential to understanding the data. All results of measurements by EPA, with the exception of Plants C and D, were obtained with a single-point sample under nonisokinetic conditions. Plants C and D utilized the elaborate multipoint sampling and flow measurement devices shown in Figure 7. Consequently, it was only on the latter two plants that sampling could be accomplished in accordance with accepted practices. Therefore, more confidence can be placed in those two plants which averaged less than 1.2 lb TF/TAP. These levels were achieved at both plants even without a secondary control device.

From the summary of results as presented in Figure 12, it is obvious that good hood capture efficiency can limit secondary emissions to 1.5 lb TF/TAP or less without a secondary control device.

It should be pointed out, however, that this degree of control has not been demonstrated for the VSS cell using only the primary control system. A new VSS system may require a secondary control system to achieve the level of emissions required by the standard of performance.

E. Data Base - Carbon Anode Bake Plant Emissions

The source of fluoride emissions from the carbon anode bake plant is the anode remnants or "butts" returned from the primary aluminum plant. Although typical operating procedures call for removal of fused cryolite from the surface of the

butts before they are ground and mixed with hot coal-tar pitch, the absence of quality control or supervisory emphasis was obvious during EPA plant visits. We speculate that the recommended level of control may be achievable by better cleaning of anode remnants.

Two domestic carbon anode bake plants were measured. The control equipment on either was designed specifically for fluorides. Each plant uses an electrostatic precipitator (ESP) to control organic and particulate emissions. Before entering the ESP, the gases from the anode plant are treated in a wet conditioner to improve the effectiveness of collection. Although some incidental fluoride removal probably occurs, the wet conditioner is designed to control gas temperature. Results of measurements from the first plant reveal average emissions of 0.90 pound of total fluoride per ton of carbon anodes produced (lb TF/TCAP), as shown in Figure 13, (A). As all the carbon anode production is consumed outside, the emission levels can be converted to their equivalent aluminum production. This conversion indicates average emissions of 0.45 lb TF/TAP. Results from the second anode bake plant reveal average emissions of 1.25 lb TF/TCAP (B). This plant sells anodes to other aluminum reduction plants; therefore, no direct correlation with actual aluminum production was possible. However, based on an estimate commonly used of 1,000 pounds of anode consumed per ton of aluminum produced, average emissions were calculated as 0.63 lb TF/TAP.

It appears that the best controlled carbon anode bake plant is in Norway.[11] It uses an electrostatic precipitator, a venturi scrubber, and a spray tower scrubber in series. Arrangements could not be made to measure this plant.

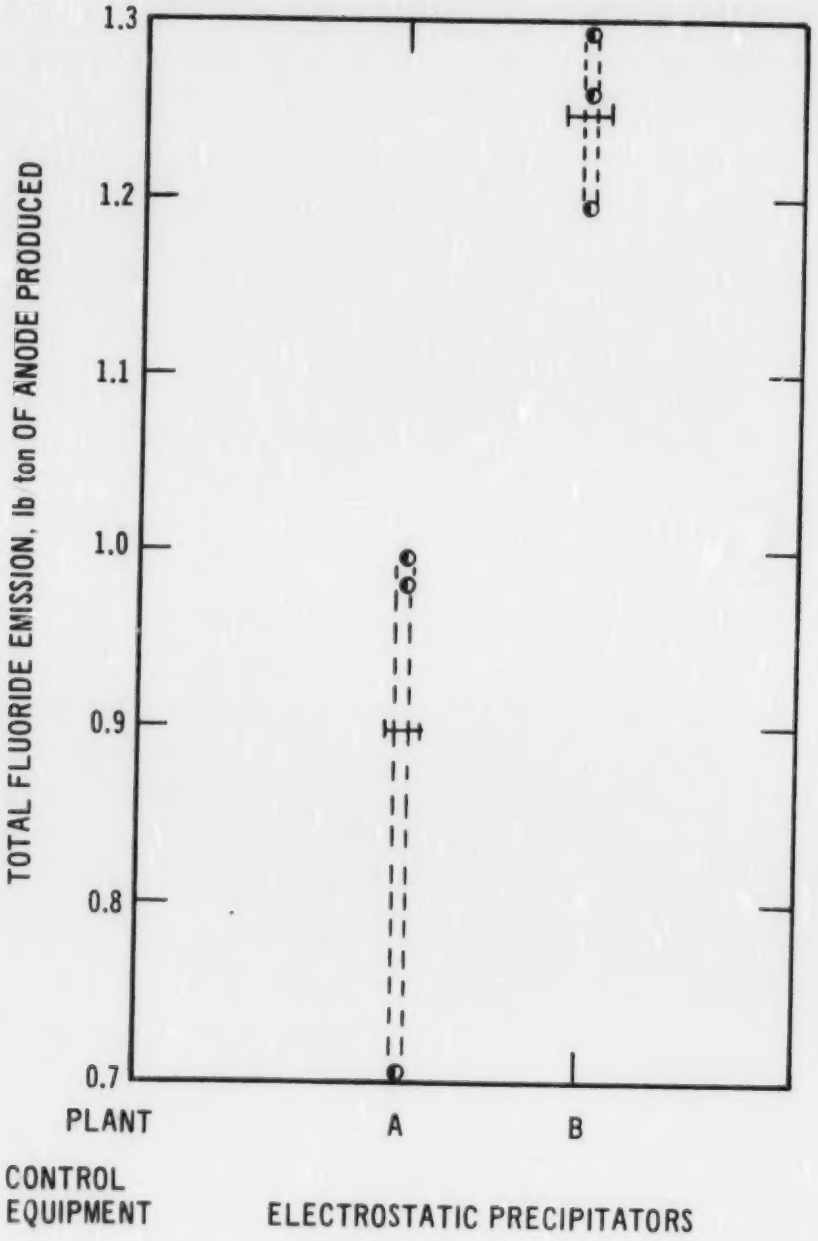


Figure 13. Carbon anode bake plant emissions.

Using data from studies of standards of performance for the phosphate fertilizer industry, we conservatively projected that emissions from anode plants can be controlled with 90 percent efficiency. Calculations based on the highest emission rate from the two domestic plants (1.33 lb TF/CAP) indicate a bake plant could achieve 0.12 lb TF/TCAP.

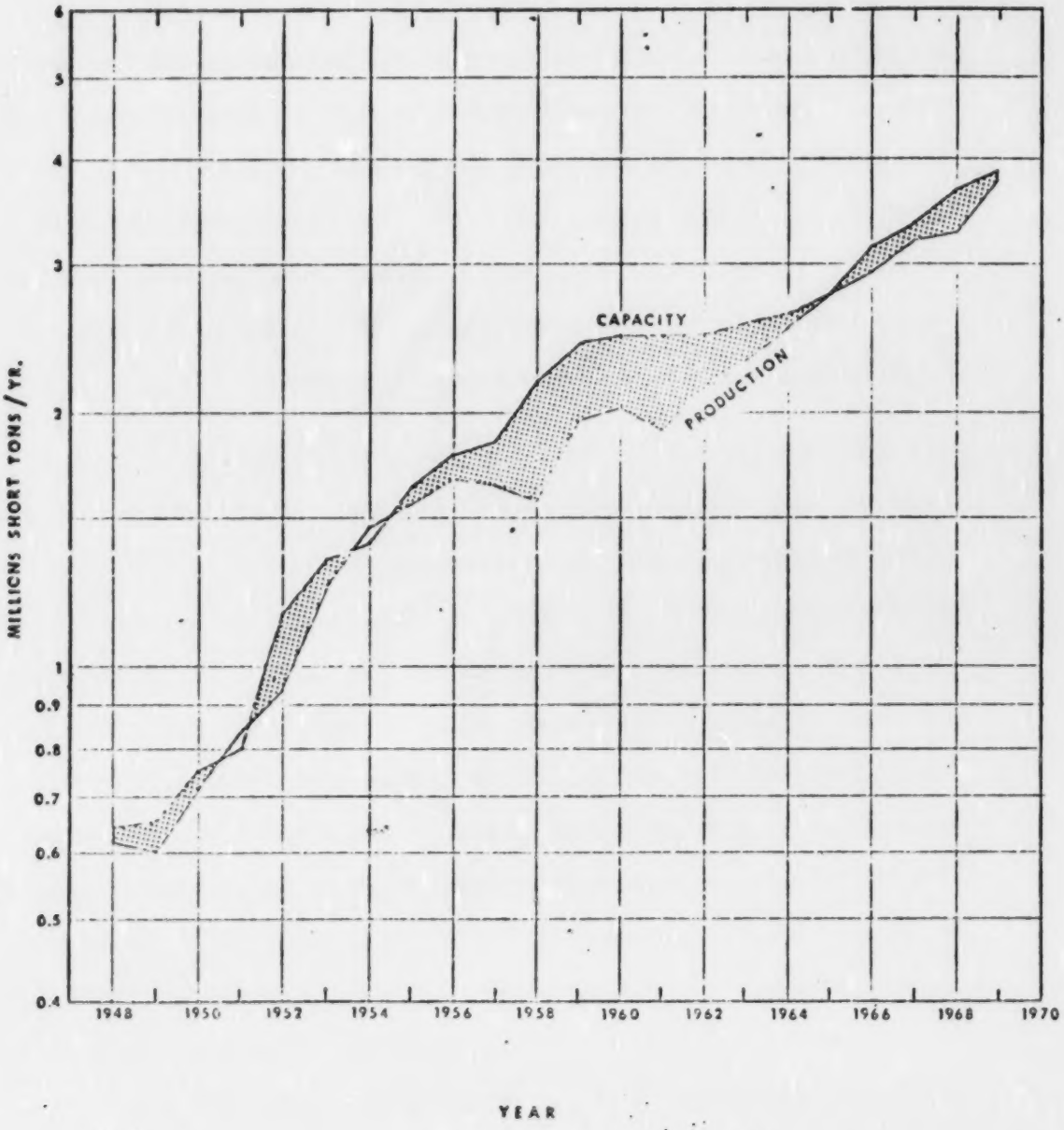
F. Cost Analysis of Alternative Fluoride Control Systems

1. Introduction

The purpose of this section is to report the expected capital and annual costs for the control devices necessary to meet the proposed standard of performance. Generally two sizes of model plants are analyzed to show how the control cost changes with size. However, in the primary aluminum industry the control cost per ton of aluminum production is not substantially affected by the size of the plant. This is due to the physical arrangement of the potlines and the control systems.

The basis for coating the control systems was to consider control device modules (i.e., several aluminum reduction cells ducted together and vented to a common control device located in the area between the potrooms). Thus, to control a larger plant additional modules are added. The use of this method reduces the usual economics of scale associated with control of larger plants. The capital costs for each of the models discussed in the next section are reported in $/ton of annual capacity. The annual costs are reported in $/ton of aluminum that would be produced at full capacity rather than in $/ton of actual aluminum production. Historically the ratio of production to capacity has varied widely, as shown in Figure 14. Therefore, $/ton of capacity is a more stable number which can easily be converted to $/ton of production for any given production/capacity ratio.

Numerous combinations of control devices have and could be used to control emissions from aluminum smelters. Each system has a different cost and control effectiveness. Normally the control systems with higher



DATA SOURCE: ALUMINUM STATISTICS, 1969 THE ALUMINUM ASSOCIATION

Figure 14. Excess capacity U.S. primary aluminum industry.

efficiency cost more. For two of the cell types in this industry, the expected cost-effectiveness relationship does not hold. In fact, the most effective control systems for the pre-bake and vertical-stud Soderberg cells are relatively low-cost systems due to credits from recovered material. This effect can be seen on Figures 15 and 16, which display the net annual control costs vs. control effectiveness for several control systems. Thus, the proposed standard which is based on best demonstrated technology is also the "best" from a control cost standpoint, that is, a lower cost system.

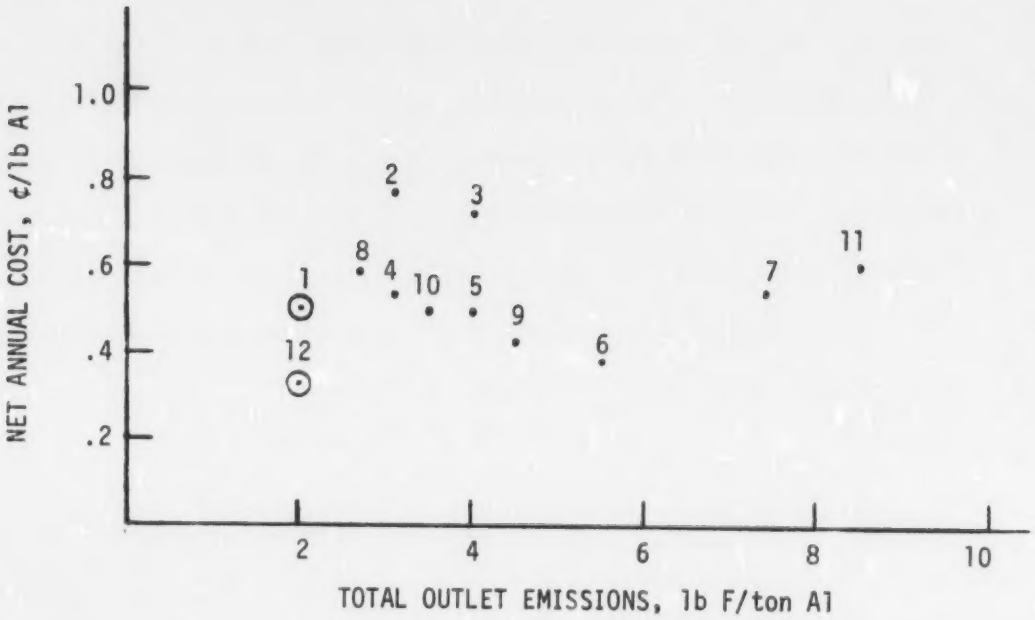
The control cost for the horizontal stud Soderberg cells will be higher since the complex wet control system necessary to meet the proposed standard does not yield any credits for recovered material. In this case the usual relationship between cost and effectiveness is shown in Figure 17.

2. Model Plants

a. Prebake Cells

Since prebake cells can be tightly hooded, the proposed standard can be met by a good primary control system for the gases collected from the reduction cells. With a good primary control system, no secondary control devices should be required on the pot room roof vents.

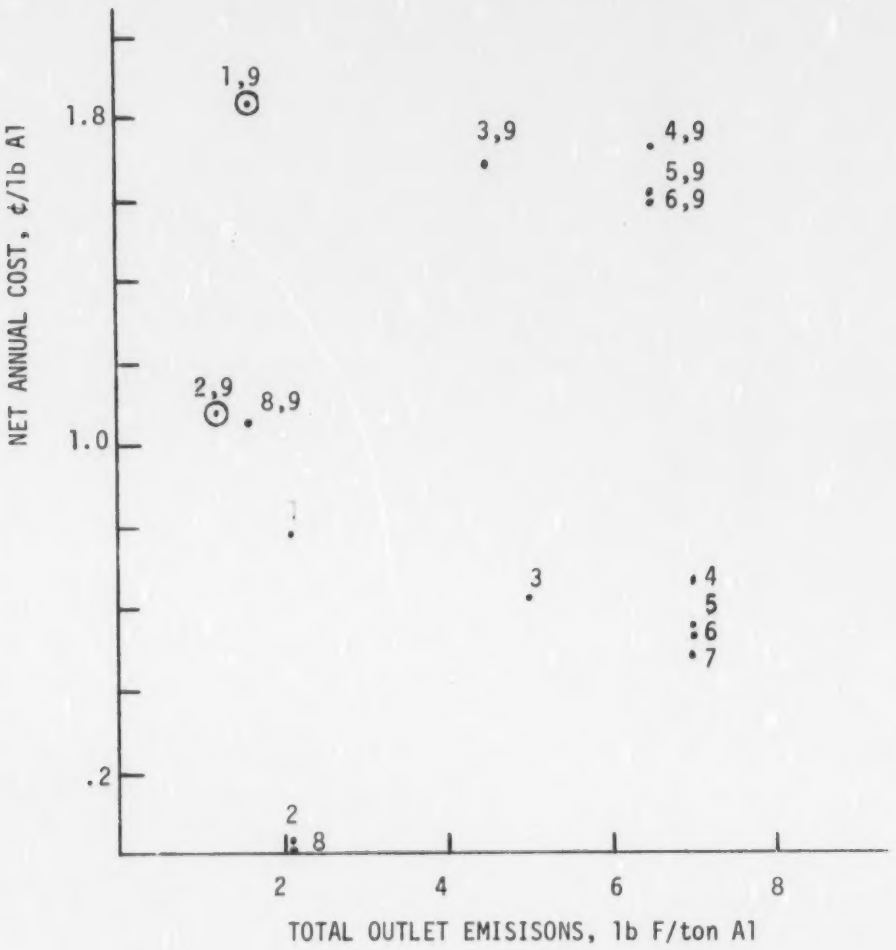
One of the most attractive control systems (the fluidized-bed dry scrubber--FBDS) for prebake cells uses a fluidized bed of alumina to absorb the gaseous fluorides and a baghouse to trap the particulate emissions and any entrained alumina. A second similar system (the



Primary Control Equipment

1. Fluid Bed Dry Scrubber
2. Miltiple Cyclones plus Venturi Scrubber
3. Miltiple Cyclones plus High Pressure Spray Screen
4. Dry Electrostatic Precipitator plus Spray Tower
5. Multiple Cyclones plus Cross Flow Packed Bed Scrubber
6. Multiple Cyclones plus Spray Tower
7. Spray Tower
8. Multiple Cyclones plus Dry Electrostatic Precipitator plus Spray Tower
9. Multiple Cyclones, plus Vertical Flow Packed Bed Scrubber
10. Multiple Cyclones, plus Floating Ball Wet Scrubber
11. Chamber Scrubber
12. Injected Alumina Dry Scrubber

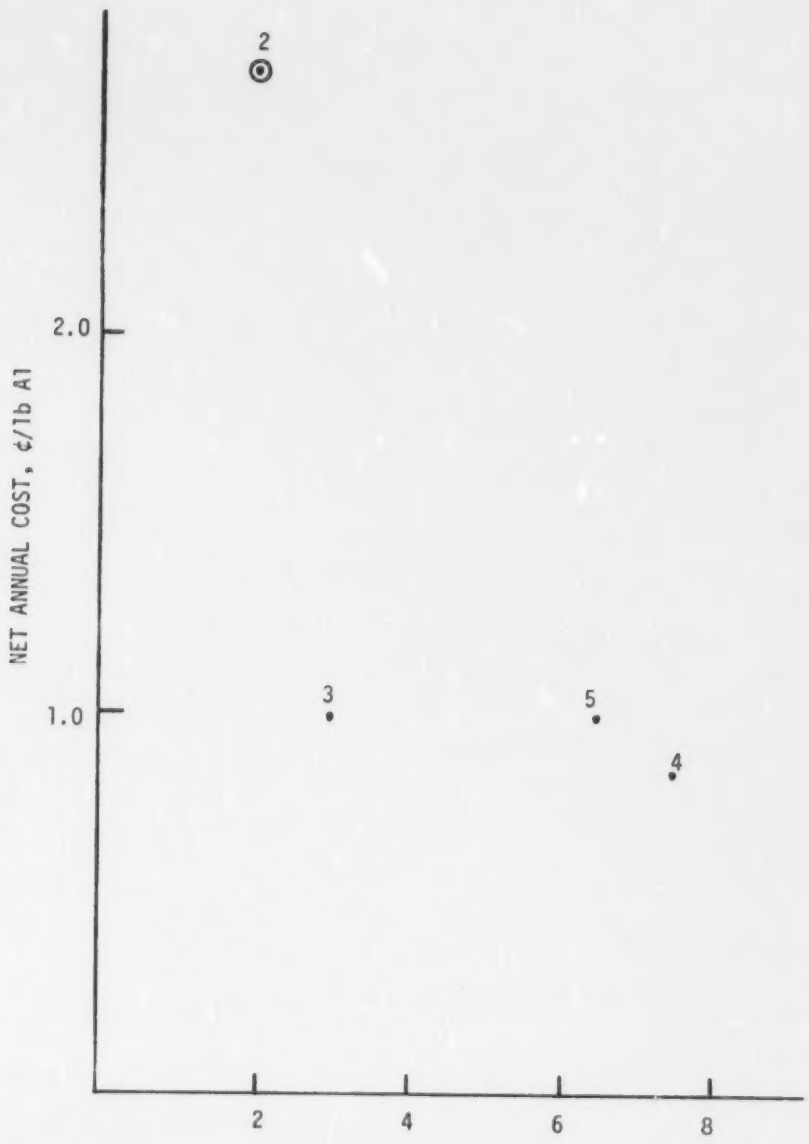
Figure 15. Cost/ effectiveness plot for prebake process.



Primary Control Equipment

1. Spray Tower plus Wet Electrostatic Precipitator
2. Fluid-Bed Dry Scrubber
3. Dry Electrostatic Precipitator Plus Spray Tower
4. Multiple Cyclones plus Venturi Scrubber
5. Multiple Cyclones plus High-Pressure Spray Screens
6. Multiple Cyclones plus Cross Flow Packed Bed Scrubber
7. Spray Tower
8. Injected Alumina Dry Scrubber
9. Spray Screen - Secondary Control

Figure 16. Cost effectiveness plot for VSS process.



1. Cross Flow Packed Bed Scrubber plus Wet Electrostatic Precipitator
2. Spray Tower plus Wet Electrostatic Precipitator
3. Cross Flow Packed Bed Scrubber
4. Spray Tower
5. Floating Ball Wet Scrubber

Figure 17. Cost effectiveness plot for HSS process.

injected alumina dry scrubber--IADS) based on the same principle injects the alumina into the gas stream where adsorption of the fluorides takes place. The spent alumina is then fed to the reduction cell. One of the attractive features of the dry systems is that the captured alumina and fluorides are returned to the cells, thus reducing input material costs.

Table 3 shows the capital and annual costs for control of prebake cells. The costs for control of the vertical and horizontal stud Soderberg cells are also shown for easy comparison. Included in the capital cost are the primary collection system (hoods and ducts), the fans and other auxiliary equipment, the collection device, and water treatment facilities if required. All control costs are given in terms of 1972 dollars. Current costs are approximately 20 percent greater.

Since the carbon anodes used in the prebake cells are made in a separate operation, the anode baking furnace emissions must be added to the reduction cell emissions in order to determine the total emissions which are covered by the proposed standard. Table 4 presents the range of control costs for the anode baking furnace. The low end of the range is based on a control system consisting of a precooler, dry electrostatic precipitator, and a wet scrubber. The high end of the range is based on using a wet scrubber followed by a wet electrostatic precipitator. A water treatment system is included in the costs. Table 5 shows a summary of the control cost range for the three cell types.

Table 3. COST OF POTLINE CONTROLS FOR ALUMINUM REDUCTION SMELTERS[a]

Cell Type	Prebake		Vertical Stud Soderberg		Horizontal Stud Soderberg
Control Equipment[b]	1°-FBDS	1°-IADS	1°-FBDS 2°-SS	1°-ST+WESP 2°-SS	1°-ST+WESP
Capital Cost ($/Ton)	67[c]	59	95[c]	117	193
Annual Cost ($/Ton)					
Operating and Maintenance	5.57	4.35	9.70	11.69	11.89
Depreciation 8%					
Administrative Overhead 5%					
Property Tax, Insurance 2%	10.02	8.80	14.31	17.49	28.91
15%					
Interest 8%	5.36	4.70	7.64	9.32	15.46
Royalty[d]	.33	--	.33	--	--
Gross Annual Cost	21.28	17.85	31.98	38.50	56.26
Credits (Alumina @ $0.032/lb, and Fluoride @ $0.25/lb	(10.54)	(10.54)	(9.19)	--	--
Net Annual Cost ($/ton)	10.74	7.31	22.79	38.50	56.26
(¢/lb)	0.54	0.37	1.14	1.93	2.81

[a]Singmaster & Breyer, Air Pollution Control in the Primary Aluminum Industry, July 23, 1973, under Contract No. CPA 70-21 for the Environmental Protection Agency. Updated to 1972 dollars.

[b]FBDS - Fluidized Bed Dry Scrubber
IADS - Injected Alumina Dry Scrubber
ST - Spray Tower
WESP - Wet Electrostatic Precipitator
SS - Spray Screen

[c]In addition, a $100,000 one-time fee is charged per company for this design.

[d]Correspondence with Mr. Holmes, Manager, Badin (N.C.) Works, ALCOA.

1° = primary control system
2° = secondary control system

Table 4. CONTROL COSTS FOR PREBAKE ANODE BAKING FURNACES

Control Equipment	PC+DESP+WS or WS+WESP[a]
Capital Cost ($/Ton)	6 - 12
Annual Cost (¢/lb)	0.088 - 0.20

[a]PC - Precooler
WS - Wet Scrubber
DESP - Dry Electrostatic Precipitator
WESP - Wet Electrostatic Precipitator

Table 4. CONTROL COSTS FOR PREBAKE ANODE BAKING FURNACES

Control Equipment	PC+DESP+WS or WS+WESP[a]
Capital Cost ($/Ton)	6 - 12
Annual Cost (¢/lb)	0.088 - 0.20

[a]PC - Precooler
WS - Wet Scrubber
DESP - Dry Electrostatic Precipitator
WESP - Wet Electrostatic Precipitator

Table 5. SUMMARY OF CONTROL COSTS FOR PRIMARY ALUMINUM PLANTS

Costs	PB (Reduction Cells Plus Anode Baking Furnace)	VSS	HSS
Capital Cost ($/Ton)	65 to 79	95 to 117	193
Annual Cost (¢/lb)	0.45 to 0.74	1.14 to 1.93	2.82

b. Vertical Stud Soderberg Cells

The physical arrangement of the vertical stud Soderberg (VSS) cell makes complete collection of the gases difficult. The control costs reported for the VSS cells in Tables 3 and 5 are based on the assumption that a secondary control system on the potroom roof vents will be necessary to meet the proposed standard.

The primary control systems reported are the FBDS and spray tower plus wet electrostatic precipitator combination (ST + WESP). The secondary control system is a spray screen device (SS). Although no VSS cells are presently controlled with the IADS system, there does not seem to be any reason why they couldn't be controlled with the IADS. The costs for a primary IADS system would be less than the FBDS system by the same proportion that it is for the prebake cell.

The present hood design for VSS cells allows enough gas to escape into the potroom so that the total emissions from a plant with only a primary control system would exceed the proposed standard by a factor of 2 to 5. The costs reported here assume that a secondary system will be required. Since the secondary system is expensive and relatively inefficient, some manufacturers may elect to improve the hooding to raise the collection efficiency so that a primary control system alone will meet the proposed standard. This alternative could result in lower costs than for the system reported here, but it has yet to be proven. Table 6 shows the breakdown of control cost between the primary and secondary control systems. Obviously, there is considerable cost incentive to improve the hooding so that a primary system alone could meet the proposed standard.

Table 6. CONTROL COSTS FOR VERTICAL STUD SODERBERGS[a]

	Control System 1			Control System 2		
	Primary	Secondary	Total	Primary	Secondary	Total
Control Equipment	ST+WESP	SS	---	FBDS	SS	---
Capital Cost ($/Ton)	53	64	117	31[b]	64	95
Annual Cost ($/Ton)						
Operating and Maintenance	4.28	7.41	11.69	2.29	7.41	9.70
Depreciation 8%						
Administrative Overhead 5%						
Property Tax, Insurance 2%						
15%	7.91	9.58	17.49	4.73	9.58	14.31
Interest 8%	4.21	5.11	9.32	2.53	5.11	7.64
Royalty[c]	---	---	---	0.33	---	0.33
Gross Annual Cost	16.40	22.10	38.50	9.88	22.10	31.98
Credits (Alumina @ $0.032/lb, flouride @ $0.25/lb)	---	---	---	(9.19)	---	(9.19)
Net Annual Cost ($/ton)	16.40	22.10	38.50	0.69	22.10	22.79
(¢/lb)	0.82	1.11	1.93	0.03	1.11	1.14

[a]Singmaster and Breyer, Air Pollution Control in the Primary Aluminum Industry, July 23, 1973, under Contract CPA 70-21 for the Environmental Protection Agency. Updated to 1972 dollars.

[b]In addition, a $100,000 one-time fee is charged per company for this design.

[c]Correspondence with Mr. Holmes, Manager, Badin, N. C. Works, ALCOA.

c. Horizontal Stud Soderberg Cells

The horizontal stud Soderberg cells might be hooded well enough to meet the proposed standard by the installation of a good primary system alone. The control system reported in Tables 3 and 5 is a wet scrubber plus a wet electrostatic precipitator combination. This is the only system that has been demonstrated at this time. However, it is an expensive system with no credits for recovery of fluorides or alumina. The hydrocarbon tars given off in this process have prevented the use of the dry systems up to this time. Research is being done to determine the technical and economic feasibility of using the dry systems for this type of cell. Indications are that if the dry systems can be used, the costs will be significantly reduced for control of the horizontal cells.

3. Monitoring System Cost

In order to accurately measure the emissions escaping through the roof vents, a representative sample must be taken. One way to accomplish this is to install a permanent sample collection system. The system consists of a sampling manifold along the roof vent which is ducted to an exhaust fan and stack. A composite sample of the roof vent gas can then be measured at the stack. Several anemometers are installed along the roof vent to measure the gas velocity. The estimated capital cost of this system in a potroom is $8500. For a plant producing 100,000 tons per year, the total cost would be about $34,000 (assuming four potrooms). The annual cost for this system is about $8400 excluding the labor cost for collecting and analyzing the samples. The annual cost per pound of aluminum is about 0.004¢/lb.

4. Control Costs to Meet Existing State Standards

Table 7 shows the estimated average emisisons, control level, and control costs for existing plants as of 1971. In the absence of a new source performance standard, new aluminum plants would probably invest at least as much as the 1971 average for control equipment. As shown by the cost ranges in Table 7, the costs of controlling some prebake and VSS cells to levels required by existing State standards are now near the costs estimated for the proposed standard.

A "high side" approximation of the added cost due to the new source performance standard can be determined by the difference between the costs in Tables 5 and 7. These results are shown in Table 8. The added cost for prebake plants is relatively small. The added cost for VSS is greater, and the added cost for the HSS is substantial.

The differential control cost would increase the control efficiency to approximately 96-97 percent from the 1971 industry average of about 74 percent. The emission rate would be reduced from the 1971 industry average of about 12 pounds per ton to 2.0 pounds per ton.

5. Cost Effectiveness of Secondary Control Systems

The preceding discussion of control costs is based on the assumption that the proposed standard can be met by the use of good hooding and a high-efficiency primary control system on the prebake and HSS cells. Because of the problem of complete hooding around the VSS cells, the VSS cell plants will probably require a secondary control system. Even with good hooding

Table 7. 1971 PRIMARY ALUMINUM INDUSTRY COSTS, CONTROL LEVEL, AND EMISSION RATE[a]

Cell Type	Capacity (1000 Tons)	Capital Cost ($/ton)	Annual Cost (¢/lb)	Overall Control Efficiency (%)	Emission Rate (lb F/ton Al)
Prebake	3020	50.10 (28-100)[b]	0.54 (0.19-1.23)	73.9	12.0
Vertical Stud Soderberg	601	60.50 (32-109)	1.00 (0.48-1.84)	82.6	8.0
Horizontal Stud Soderberg	1033	49.00	0.84	70.3	13.6
Total Industry	4654	52.20	0.67	74.2	11.8

[a]Singmaster and Breyer, Air Pollution Control in the Primary Aluminum Industry July 23, 1973, under Contract CPA 70-21 for the Environmental Protection Agency.

[b]Numbers in parentheses indicate the range of costs reported for existing plants.

Table 8. RANGE OF APPROXIMATE COST DIFFERENCES BETWEEN THE PROPOSED STANDARD OF PERFORMANCE AND EXISTING STATE STANDARDS

Costs	Prebake	VSS	HSS
Δ Capital Cost ($/ton)	14.90 to 28.90	34.50 to 56.50	144.0
Δ Annual Cost (¢/lb)	(0.09) to 0.20	0.15 to 0.93	1.98

a small amount of emissions will escape capture at the cell. Secondary control systems on the roof could be installed to remove some of these emissions. The following discussion is based on uncontrolled secondary emissions of 1.5 pounds per ton of aluminum escaping from the best primary control systems for PB and HSS cell plants.

The cost effectiveness of adding secondary controls can be illustrated by looking at two types of secondary emission control. The first type would involve the installation of a spray screen as the secondary control system on the PB and HSS cell plants. To meet the same degree of control, the VSS plant would probably have to upgrade their secondary control system to that described for the second type. The spray screen is the least expensive secondary control system, and it is estimated to achieve about a 35 percent reduction of the 1.5 pounds per ton of secondary emissions for PB and HSS cell plants.

The second type of secondary control would involve the installation of a cross flow packed bed (CFPB) scrubber on the PB and HSS plants. It is questionable whether the VSS plant could achieve this degree of control. The CFPB scrubber is highly efficient in removing gaseous fluorides, but it is not as efficient in removing small particulates. A combined removal efficiency for the 1.5 pounds per ton secondary emissions of about 60 percent has been estimated with this device. The higher cost and efficiency for the CFPB scrubber are compared with those for the spray screen and the proposed standard in Table 9. The overall efficiencies are based on a primary control system of 96 percent efficiency and uncontrolled secondary emissions of 1.5 pounds per ton of aluminum.

Table 9. COST EFFECTIVENESS OF SECONDARY CONTROL SYSTEMS

Efficiency Levels	Emissions (#F/Ton Al)	PB		VSS		HSS	
		Capital Cost ($/Ton)[a]	Annual Cost (¢/lb)	Capital Cost ($/Ton)[a]	Annual Cost (¢/lb)	Capital Cost ($/Ton)[a]	Annual Cost (¢/lb)
Proposed Standard[b] 96% Overall Efficiency	2.0	65-79	0.45-0.74	95-117	1.15-1.90	193	2.80
Control Level #2[c] 97% Overall Efficiency	1.5	111-125	1.25-1.55	197-219	2.70-3.45	257	3.09
Control Level #3[d] 98% Overall Efficiency	1.1	167-181	2.00-2.30	e		295	4.35

[a]Based on uncontrolled fluoride emissions of 50 lb/ton Al.

[b]The proposed standard is based on good hooding and high-efficiency primary control for the PB and HSS cell type. The VSS cell type has a spray screen seconday control system with associated water treatment system in addition to the primary control system.

[c]Level 2 is based on adding a spray screen secondary control system with an associated water treatment system to the requirements of the proposed standard for the PB and HSS cell types. The VSS cell type would require a more efficient secondary control system such as the CFPB scrubber.

[d]Level 3 is based on adding a CFPB scrubber secondary control system with an associated water treatment system to the requirements of the proposed standard for the PB and HSS cell types.

[e]No costs are reported for the VSS cell type to meet this level of control since it is questionable whether or how the VSS could achieve this level of control.

As shown in Table 9, the cost of control rises sharply with each increment of control efficiency, designated in the table as Proposed Standard (96 percent). Control Level #2 (97 percent), and Control Level #3 (98 percent). For example, the annual control cost for the prebake cell more than doubles in going from the proposed standard to Control Level #2 and goes up by a factor of 3 to 4 between the proposed standard and Control Level #3.

The cost effectiveness of the various control systems in terms of cost per pound of fluoride emissions captured is shown in Tables 10-12. For the prebake process shown in Table 10, the industry is currently spending $50 of capital per ton of aluminum capacity in order to capture 74 percent of the fluoride emissions from the process. This is equivalent to $1.35 per pound of fluoride captured. In order to achieve a control level of 96 percent, the industry would have to spend a total of $73 of capital per ton of aluminum capacity. Therefore, the average cost for the entire 48 pounds of fluoride that could be captured per ton of aluminum capacity amounts to $1.52. This is equivalent to $1.35 for the first 37 pounds of fluoride captured and $2.09 for the next 11 pounds of fluoride captured. It can be seen that a large gap exists between the capital costs required for fluoride control at the proposed standard level (96 percent) and Control Level #2 (97 percent). Whereas the average capital cost per pound of fluoride removed only increases from $1.52/lb to $2.45/lb, the cost of capturing the additional 0.5 pound of fluoride amounts to $92.00/lb of fluoride. The operating costs for the fluoride control systems behave in a similar manner. It costs an average of $32.00/lb of fluoride

Table 10. COST EFFECTIVENESS OF EMISSION CONTROLS FOR PREBAKE PROCESS

I. CAPITAL REQUIREMENTS OF EMISSION CONTROL

Control Level	Fluoride Captured[a]		TOTAL CAPITAL		INCREMENTAL CAPITAL	
	lb/Ton Al	%	Average Control Capital ($/Ton Al)	$ Capital Per Lb F Captured	Average Control Capital ($/Ton Al)	$ Capital Per Add'l Lb F Captured
Existing Industry Level	37.0	74	50	1.35	50	1.35
Proposed Standard	48.0	96	73	1.52	23	2.09
Control Level #2	48.5	97	119	2.45	46	92.00
Control Level #3	48.9	98	175	3.58	56	140.00

II. OPERATING COST REQUIREMENTS OF EMISSION CONTROL

Control Level	Fluoride Captured[a]		TOTAL COST		INCREMENTAL COST	
	lb/Ton Al	%	Average Control Cost (¢/lb Al)	$ Cost Per Lb F Captured	Average Control Cost (¢/lb Al)	$ Cost Per Add'l Lb F Captured
Existing Industry Level	37.0	74	0.540	0.29	0.540	0.29
Proposed Standard	48.0	96	0.625	0.26	0.085	0.15
Control Level #2	48.5	97	1.425	0.59	0.800	32.00
Control Level #3	48.9	98	2.175	0.89	0.750	37.50

[a]Based on uncontrolled fluoride emissions of 50 lb/ton Al.

captured to go from 48.0 pounds to 48.5 pounds of fluoride captured, whereas the cost of capturing the first 37.0 pounds of fluoride is $0.29/lb and the cost of capturing the next 11 pounds of fluoride is $0.15/lb.

Table 11 shows that a similar gap exists between the proposed standard level and Control Level #2 for the vertical stud Soderberg process. Capital requirements average $4.29 per pound of fluoride captured at 97 percent control versus $2.21 per pound of fluoride captured at 96 percent control, but the cost of capturing the last 0.5 pound of fluoride costs $204.00/lb versus $1.45/lb for the first 41.5 pounds of fluoride captured and $7.08 for the next 6.5 pounds of fluoride captured. Operating costs amount to $26.00/lb of fluoride captured for the last 0.5 pound captured versus $0.48/lb for the first 41.5 pounds captured and $1.63 for the next 6.5 pounds of fluoride captured.

Table 12, which measures the cost effectiveness of various control levels on the horizontal stud Soderberg process, again shows a large gap between the costs incurred at a control level of 96 percent versus a control level of 97 percent.

Table 11. COST EFFECTIVENESS OF EMISSION CONTROLS FOR VERTICAL STUD SODERBERG PROCESS

I. CAPITAL REQUIREMENTS FOR EMISSION CONTROL

Control Level	Fluoride Captured[a]		TOTAL CAPITAL		INCREMENTAL CAPITAL	
	Lb/Ton Al	%	Average Control Capital ($/Ton Al)	$ Capital Per Lb F Captured	Average Control Capital ($/Ton Al)	$ Capital Per Add'l Lb F Captured
Existing Industry Level	41.5	83	60	1.45	60	1.45
Proposed Standard	48.0	96	106	2.21	46	7.08
Control Level #2	48.5	97	208	4.29	102	204.00

II. OPERATING COST REQUIREMENTS FOR EMISSION CONTROL

Control Level	Fluoride Captured[a]		TOTAL COST		INCREMENTAL COST	
	Lb/Ton Al	%	Average Control Cost (¢/lb Al)	$ Cost Per Lb F Captured	Average Control Cost (¢/lb Al)	$ Cost Per Add'l Lb F Captured
Existing Industry Level	41.5	83	0.995	0.48	0.995	0.48
Proposed Standard	48.0	96	1.525	0.64	0.530	1.63
Control Level #2	48.5	97	3.075	1.27	1.550	62.00

[a]Based on uncontrolled fluoride emissions of 50 lb/ton Al.

Table 12. COST EFFECTIVENESS OF EMISSION CONTROLS FOR HORIZONTAL STUD SODERBERG PROCESS

I. CAPITAL REQUIREMENTS FOR EMISSION CONTROL

Control Level	Fluoride Captured[a]		TOTAL CAPITAL		INCREMENTAL CAPITAL	
	Lb/Ton Al	%	Average Control Capital ($/Ton Al)	$ Capital Per Lb F Captured	Average Control Capital ($/Ton Al)	$ Capital Per Add'l Lb F Captured
Existing Industry Level	35.0	70	49	1.40	49	1.40
Proposed Standard	48.0	96	193	4.02	144	11.08
Control Level #2	48.5	97	257	5.30	64	128.00
Control Level #3	48.9	98	295	6.03	38	95.00

II. OPERATING COST REQUIREMENTS FOR EMISSION CONTROL

Control Level	Fluoride Captured[a]		TOTAL COST		INCREMENTAL COST	
	Lb/Ton Al	%	Average Control Cost (¢/lb Al)	$ Cost Per Lb F Captured	Average Control Cost (¢/lb Al)	$ Cost Per Add'l Lb F Captured
Existing Industry Level	35.0	70	0.835	0.48	0.835	.48
Proposed Standard	48.0	96	2.800	1.16	1.965	3.02
Control Level #2	48.5	97	3.900	1.61	1.100	44.00
Control Level #3	48.9	98	4.350	1.78	0.450	22.50

[a]Based on uncontrolled fluoride emissions of 50 lb/ton Al.

G. Economic Analysis of Proposed Standards

1. Economic Profile: Domestic Primary Aluminum Industry

The domestic primary aluminum industry has been characterized until rather recently by a large increase in primary ingot production capacity that has not been matched by a corresponding expansion of demand. This situation led to excess capacity in the industry along with larger than normal inventory accumulations. This, in turn, caused a great deal of downward pressure on primary ingot prices and resulted in reduced profits for domestic producers. Not only did the rate of expansion of domestic primary ingot production capacity outstrip domestic demand, but total free world production capacity expanded at a faster rate than the growth in total free world demand. This led to a world-wide situation of over-capacity and reduced prices. Recent indications are that the rate of expansion of primary ingot capacity, both domestic and foreign, has slowed to a rate that more nearly matches future projections of demand for aluminum. This is now beginning to be reflected in rising prices for primary aluminum ingot. Increased profitability for individual producers is expected to follow rising ingot prices.

Table 13 summarizes the major uses of aluminum ingot and mill products for the years 1967 and 1972. Whereas the total uses of aluminum increased by 34 percent and 4.5 million tons in 1967 to 6.0 million tons in 1972, the two categories of building/construction and containers/ packaging increased by 64 and 109 percent, respectively. Usage of aluminum in the transportation sector, which occupies second place in terms of total

Reproduced from best available copy.

Table 13. DOMESTIC ALUMINUM USAGE
1967-1972

End Use	Total Shipments of Ingot and Mill Products (Short Tons) 1967	1972	% Change
Building & Construction	964,500	1,584,000	64
Transportation	889,500	1,107,000	24
Containers & Packaging	434,000	908,000	109
Electrical	624,000	761,500	22
Consumer Durables	415,500	553,500	33
Machinery & Equipment	308,500	368,000	19
Exports	328,500	281,000	(14)[a]
Other	508,500	427,000	(16)[a]
	4,473,000	5,990,000	34

SOURCE: Aluminum Statistical Review - 1972, The Aluminum Association.

[a]() Denotes decrease.

shipments, increased by 24 percent between 1967 and 1972. The use of aluminum in the building and construction industry is by far the largest applications of aluminum. This use accounted for over 26 percent of the total used in 1972. The next largest market in 1972, the transportation sector, accounted for 18 percent of the total use of aluminum ingot and mill products.

Table 14 summarizes the major sources of supply of primary aluminum ingot and mill products for 1967 and 1972. Domestic sources (both primary and secondary) are the major components of total supply, accounting for 88 percent of the total in 1967 and 87 percent of the total in 1972. The supply of aluminum from domestic sources increased by 27 percent between 1967 and 1972. Output from domestic primary producers increased by 26 percent during this period. Recovery of imported scrap almost doubled between 1967 and 1972, and the total supply of aluminum from foreign sources increased by almost 50 percent during the period. Imports of primary metal, primarily from Canada, increased by 47 percent between 1967 and 1972, and account for approximately 10 percent of the total aluminum supplies.

Table 15 points out the increase in domestic primary aluminum capacity between 1967 and 1972. Total domestic capacity increased by 44 percent from 3.3 million tons in 1967 to 4.8 million tons in 1972. Alcoa, with a capacity increase of 420,000 tons (37 percent of its 1967 capacity of 1,150,000 tons) contributed 29 percent of the total increase of 1.5 million tons. Three new firms entered the primary aluminum makret between 1967 and 1972. These three firms, National Southwire, Revere, and Noranda,

Table 14. DOMESTIC ALUMINUM SUPPLIES
1967-1972

	1967		1972		
	Tons[a]	% of Total	Tons[a]	% of Total	% Increase 1967-1972
Domestic Primary Production	3,269,500	69.7	4,122,500	68.1	26
Domestic Secondary Recovered	878,000	18.7	1,126,000	18.6	28
Total Domestic Sources	4,147,500	88.4	5,248,500	86.7	27
Primary Imports	449,500	9.6	659,500	10.9	47
Imported Scrap Recovered	27,500	0.6	47,000	0.8	71
Imported Mill Products	65,500	1.4	96,000	1.6	47
Total Imported	542,500	11.6	802,500	13.3	48
Total Supply (Excluding Stockpile)	4,690,000	100.0	6,051,000	100.0	29

[a]All supplies in short tons.

SOURCE: Aluminum Statistical Review - 1972, The Aluminum Association.

Table 15. DOMESTIC PRIMARY ALUMINUM CAPACITY
1967-1972

Producers	1967 (Tons)[a]	1972 (Tons)[a]	Increase	
			Tons	%
Alcoa	1,150,000	1,570,000	429,000	37
Reynolds	815,000	975,000	160,000	20
Kaiser	670,000	710,000	40,000	6
Ormet	240,000	250,000	10,000	4
Howmet	76,000	217,500	141,500	186
Martin Marietta	88,000	201,000	113,000	128
Anaconda	100,000	180,000	80,000	80
National Southwire	---	180,000	180,000	NA
Consolidated	106,000	175,000	69,000	65
Amax	76,000	130,500	54,500	72
Revere	---	112,000	112,000	NA
Noranda	---	70,000	70,000	NA
Total Domestic Capacity	3,321,000	4,771,000	1,450,000	44

[a]All quantities in short tons.

SOURCE: Aluminum Statistical Review - 1972, The Aluminum Association.

contributed 362,000 tons of capacity, or 25 percent of the total increase of 1.5 million tons. The total increase in domestic primary aluminum capacity between 1967 and 1972 of 44 percent was approximately 30 percent more than the increase in total aluminum usage of 34 percent for the same time period (Table 13) and almost 50 percent more than the increase in total supplies, both domestic and foreign, as shown in Table 14.

Table 16 illustrates the point that increases in primary aluminum production capacity were not limited only to domestic producers. While domestic capacity was increasing by 44 percent, total free world capacity was increasing by 68 percent to a total of 12,062,000 tons per year for the time period 1967-1972. Australia and New Zealand increased total capacity by 210 percent (over 25 percent per year) to a total capacity of 388,000 tons per year in 1972. Japan, starting with a 1967 production capacity of 436,000 tons per year, grew by 206 percent (over 25 percent per year) to a total capacity in 1972 of 1,332,000 tons per year and thereby took over third place from Canada in the ranking of major aluminum producers.

Table 17 indicates that growth in free world production capacity was not matched by production increases. Total free world production of 6,754,000 tons in 1967 represented 94 percent of the total free world capacity of 7,180,000 tons per year (Table 16). While total free world capacity was increasing by 68 percent to 12,062,000 tons per year, the growth in free world production was only 49 percent, resulting in a decrease of plant utilization to 84 percent for the free world overall. The United

Table 16. FREE WORLD PRIMARY ALUMINUM CAPACITY
1967 - 1972

Countries	1967 (Tons)[a]	1972 (Tons)[a]	% Increase
United States	3,321,000	4,771,000	47
Canada	1,050,000	1,210,000	15
Latin America (incl. Mexico)	139,000	259,000	86
Europe	1,790,000	3,360,000	88
Japan	436,000	1,332,000	206
India	125,000	231,000	85
Africa & Mid-East	172,000	451,000	162
Australia & New Zealand	125,000	388,000	210
Other	22,000	60,000	173
Total Free World	7,180,000	12,062,000	68

[a]All quantities in short tons/year.

SOURCE: U. S. capacities from Aluminum Statistical Review - 1972, The Aluminum Association. 1967 capacities for other countries from Aluminum-Profile of an Industry, Farin and Reibsamen (Metals Week), 1969. 1972 capacities for other countries from Survey of Free World Primary Aluminum Capacity, 1971-1976, Stewart Spector, Oppenheimer & Company, February 28, 1972.

Table 17. FREE WORLD PRIMARY ALUMINUM PRODUCTION AND PERCENT UTILIZATION 1967 - 1972

	1967		1972	
	Production (Tons)[a]	% of Capacity	Production (Tons)[a]	% of Capacity
United States	3,269,000	98	4,122,000	86
Canada	975,000	93	1,020,000	84
Latin America (Incl. Mexico)	103,000	74	239,000	92
Europe	1,664,000	93	2,650,000	79
Japan	421,000	97	1,119,000	84
India	106,000	85	197,000	85
Africa & Mid-East	97,000	56	359,000	80
Australia & New Zealand	102,000	82	323,000	83
Other	17,000	77	52,000	87
Total Free World	6,754,000	94	10,081,000	84

[a]All quantities in short tons.

SOURCE: Aluminum Statistics - 1972, The Aluminum Association.

States experienced a decline in plant utilization from 98 percent in 1967 to 86 percent in 1972. During the same time period Europe declined from 93 to 79 percent, and Japan declined from 97 to 84 percent. Some countries, notably Latin America and Africa/Mideast, increased their plant utilization between 1967 and 1972, but the net result was still a decline in utilization of free world capacity.

The rapid expansion of domestic and free world capacity relative to demand caused prices to fall for aluminum products. Aluminum producers faced with underutilized plant capacities chose to lower prices in order to increase output. Demand for aluminum, however, was not that responsive to price movements, and the end result was that prices dropped while output increased only marginally. Producers kept increasing list prices in hopes that realized prices would follow, but price discounting continued as producers attempted to retain their share of the market. The average list price for aluminum ingot in 1966 was approximately 24.5¢/lb, and discounts averaged about 0.5¢/lb. This left a realized price of approximately 24¢/lb. In 1971 the list price had risen to 29¢/lb, but discounts on the order of 8-1/2¢/lb were sometimes encountered. This meant that the realized price was as low as 20-1/2¢/lb for aluminum ingot.

Table 18 shows the effect that price-cutting and excess production capacity had upon Alcoa, Reynolds, and Kaiser. While total sales for these three firms increased by 33 percent between 1967 and 1972, net income after taxes decreased from a total of $209.9 million for the three firms in 1967 to a total of $118.1 million in 1972, a decrease of

Table 18. SELECTED FINANCIAL INFORMATION FOR THREE MAJOR DOMESTIC PRIMARY ALUMINUM PRODUCERS

	Net Sales			Inventories		
	1967[a]	1972[a]	% Change	1967[a]	1972[a]	% Change
Alcoa	$1360.8	$1753.0	28.8	$338.0	$432.8	28.1
Reynolds	804.0	1162.2	46.6	225.4	367.2	62.9
Kaiser	771.6	990.8	28.4	220.6	263.2	19.5
Total	$2936.4	$3906.0	33.0	$8785.6	$1063.2	35.7

	Net Income			Net Income (% of Sales)	
	1967[a]	1972[a]	% Change[b]	1967	1972
Alcoa	$108.4	$102.8	(5.2)	8.0	5.9
Reynolds	47.4	0.2	(99.6)	5.9	---
Kaiser	54.1	15.1	(72.1)	7.0	1.5
Total	$209.9	$118.1	(43.7)	7.2	3.0

[a]In millions of dollars.
[b]() denotes decrease.

SOURCE: Standard & Poor's Standard N.Y.S.E. Stock Reports.

over 40 percent. Profitability, as measured by net income as a percent of total sales, decreased from an average of 7.2 percent for the three firms in 1967 to 3.0 percent in 1972. Of the three firms, Reynolds was the most affected and Alcoa the least affected in terms of decrease in profitability.

It appears, however, that the aluminum industry is now beginning to experience an upturn in profitability. This is due to the increasing utilization of plant capacity, both domestic and foreign. While projections beyond 1973 must be tentative, it appears that 1973 was a year of recovery for the aluminum industry. Ingot prices increased to 29¢/lb and discounts were largely eliminated. Net income for the three major aluminum producers increased by almost 65 percent to $194 million in 1973 from $118 million in 1972. Prices for aluminum ingot continued to rise in 1974, reaching a level of 33.5¢/lb as of May 15, 1974.

2. Economic Impact on the Domestic Aluminum Industry of the Proposed Standards of Performance

The additional capital requirements and operating costs for emission control systems for new aluminum smelters are summarized in Table 19. It appears that one result of the imposition of new source standards upon the domestic aluminum industry will be the acceleration of the current trend in the industry toward the prebake process for aluminum production. Emission control costs, at the level of the proposed standard, amount to $73/ton of capacity for capital costs and 0.63¢/lb of aluminum produced for operating costs for the prebake process. This compares with capital

Table 19. SUMMARY OF EMISSION CONTROL CAPITAL REQUIREMENTS AND OPERATING COSTS FOR NEW SOURCE PRIMARY ALUMINUM SMELTERS

Process	Control Level	Emission Control System Only:	
		Capital Requirement ($/Ton Capacity)	Annual Cost (¢/lb Al)
Prebake	1) Average Existing (74%)[a]	50	0.54
	2) Proposed Standard (95%)	73	0.63
	3) Control Level #2 (97%)	119	1.43
	4) Control Level #3 (98%)	175	2.18
Vertical Stud Soderberg	1) Average Existing (83%)[a]	60	1.00
	2) Proposed Standard (96%)	106	1.53
	3) Control Level #2 (97%)	208	3.08
Horizontal Stud Soderberg	1) Average Existing (70%)[a]	49	0.84
	2) Proposed Standard (96%)	193	2.80
	3) Control Level #2 (97%)	257	3.90
	4) Control Level #3 (98%)	295	4.35

[a]Source for current industry statistics: Air Pollution Control in the Primary Aluminum Industry, Singmaster and Breyer, July 23, 1973.

requirements and operating costs of $106/ton of capacity and 1.53¢/lb of aluminum produced, respectively, for the vertical stud process and $193/ton of capacity and 2.80¢/lb of aluminum produced for the horizontal stud process. Emission control costs are definitely less expensive for the prebake process. This fact, coupled with the slightly higher power requirement of the Soderberg processes, will tend to limit severely the number of future new installations utilizing either Soderberg process. As mentioned previously, three new firms entered the primary aluminum market between 1967 and 1972. These firms all utilize the prebake process in their smelters. This means that the prebake process accounts for over 60 percent of the total primary aluminum production in the United States.

Table 19 shows that the proposed standard only marginally increases the pollution control costs over what the industry is currently spending to control the prebake process. Capital costs for pollution control equipment would be increased from $50/ton of capacity to $73/ton of capacity. As a point of reference, the capital requirements for an aluminum smelter without any allocations for bauxite or alumina facilities is $750 to $1000/ton of capacity. Annualized operating costs would increase by 0.09¢/lb, from 0.54¢/lb to 0.63¢/lb. Control of emissions, however, is increased from 74 to 96 percent.

The cost differential between the proposed standard and the average existing industry practice is much greater for the Soderberg processes than for the prebake process. This fact further supports the conclusion that new aluminum smelters would be expected to be predominantly of the prebake variety.

It is concluded that the major impact of the proposed and new source performance standard for aluminum smelters is to further hasten the trend toward the increased utilization of the prebake process. Future growth in the domestic aluminum industry should not be significantly impeded by the relatively small differential between the cost of emission control at the level of the proposed standard versus the average costs currently being incurred in the industry.

It is in the evaluation of the economic impact upon the domestic aluminum industry of control levels more stringent than the proposed standard that uncertainties arise. For example, Table 19 shows that to achieve 97 percent control of emissions from the prebake process, the capital requirements for emission control equipment amount to $119 per ton of installed capacity; an increase of $69/ton over the current industry level of $50/ton of capacity. Annualized operating costs amount to 1.43¢/lb of aluminum as opposed to current levels of 0.54¢/lb of aluminum, an increase of 0.89¢/lb. The capital requirements and annualized operating costs at a more stringent control level for the prebake process (Control Level #3) amount to a capital requirement of $175/ton of capacity and annualized operating costs of 2.18¢/lb of aluminum. Facing costs of this magnitude, the prospective smelter owner has the following alternative courses of action:

1. Utilize a non-polluting smelting process.
2. Build a conventional smelter in the U.S. and increase prices to cover the additional emission control costs.
3. Build a conventional smelter in the U.S. and absorb the emission control costs.

4. Locate a conventional smelter in Canada.

5. Locate a conventional smelter elsewhere outside the U.S.

6. Do not build a smelter. The U.S. demand would have to be satisfied by foreign smelters.

Before discussing the feasibility of the alternatives listed above, it is necessary to project the future domestic aluminum capacity requirements through 1980. This is done in Table 20. The basic assumptions underlying Table 20 are as follows:

1. Growth in supplies averaging 7.5 percent per year between 1971 and 1980,

2. Mill imports, secondary recovery, and primary imports at the same percentage level in 1980 as in 1972,

3. Stockpile sales of 77,000 tons/year in 1980, according to current GSA disposal schedule, and

4. Industry operating ratio of 95 percent.

Given the above assumptions, then, domestic capacity must increase from 4.8 million tons in 1972 to 7.2 million tons in 1980, an increase of 2.4 million tons. The bulk of the increase (1.8 million tons) will have to be installed between 1977 and 1980 because a lead time of approximately 3 years is needed for construction of a smelter, and the industry plans for 1977 are fairly well established. As with any projection, however, future conditions could warrant revisions in the forecast. Table 21 shows the current projection of future industry capacity by company through 1977.

Table 20. PROJECTED DOMESTIC ALUMINUM SUPPLIES
1972 - 1980

	1972		1974		1977		1980	
	Tons[a]	%	Tons[a]	%	Tons[a]	%	Tons[a]	%
Primary Production	4,122	68.8	4,900	69.7	5,436	64.7	6,813	68.1
Stockpile Sales	6	0.1	120	1.7	77	0.9	77	0.8
Primary Imports	657	11.0	670	9.5	1,233	14.7	1,100	11.0
Total Primary Ingot	4,785	79.9	5,690	80.9	6,746	80.3	7,990	79.9
Secondary Recovery	1,108	18.5	1.275	18.1	1,554	18.5	1,850	18.5
Mill Imports	95	1.6	70	1.0	100	1.2	160	1.6
Total Supplies	5,988	100.0	7,035	100.0	8,400	100.0	10,000	100.0
Industry Capacity (Thousand Tons)	4784		4904		5436		7171	
Operating Ratio	86%		100%		100%		95%	

[a]Thousand

SOURCE: EPA-generated with exception of information for 1972 and 1974 and projected industry capacity for 1977, are from Survey of Free World Primary Aluminum Capacity, 1971-1976, Stewart Spector, Oppenheimer and Company.

Table 21. PLANNED CAPACITY ADDITIONS TO THE DOMESTIC ALUMINUM INDUSTRY
1972 - 1977
(Thousands Tons)

Company	1972 Capacity	Capacity Additions 1973	1974	1975	1976	1977	Total Additions	1977 Capacity
Alcoa	1570	-0-	-0-	-0-	45	70	115	1685
Reynolds	975	-0-		-0-	-0-	-0-	-0-	975
Kaiser	710	-0-	-0-	-0-	-0-	-0-	-0-	710
Revere	237	-0-	-0-	-0-	-0-	-0-	-0-	237
Howmet	217	-0-	-0-	-0-	87	-0-	87	304
Martin Marietta	210	-0-	-0-	-0-	90	90[a]	180	390
Anaconda	180	120	-0-	-0-	-0-	-0-	120	300
Consolidated	180	-0-	-0-	-0-	-0-	-0-	-0-	180
National Southwire	180	-0-	-0-	-0-	-0-	-0-	-0-	180
Amax	130	-0-	-0-	-0-	75	75	150	280
Ormet	125	-0-	-0-	-0-	-0-	-0-	-0-	125
Noranda	70	-0-	-0-	-0-	-0-	-0-	-0-	70
TOTAL	4784	120	-0-	-0-	297	235	652	5436

[a]Addition uncertain at this time.

SOURCE: Survey of Free World Primary Aluminum Capacity, Stewart Spector, Oppenheimer & Company, February 22, 1973.

It should be kept in mind that the aluminum industry does not necessarily have to increase domestic capacity after 1977 to 7.2 million tons. It is possible that the industry would choose either to install the bulk of this capacity overseas or else not to install it at all, thereby allowing imports to supply the domestic aluminum needs. The increase in capacity of 1.8 million tons after 1977 should be looked upon as the additional capacity needed to supply projected domestic aluminum needs in 1980. Where this capacity is installed, and by whom, will be discussed as a part of the previously introduced analyses of the six basic alternatives open to the smelter owner.

The first alternative open to the prospective smelter owner facing mandatory outlays for control of fluoride emissions is to utilize a smelting process that does not emit fluorides. However, there are not at this time any commercially available processes for the production of aluminum that do not emit fluorides even though there are two processes in the developmental stage that will allegedly produce aluminum without fluoride emissions. One process is the Alcoa Smelting Process and the other is the Toth Process. The relative merits and disadvantages of these two processes will not be discussed here; suffice it to say that neither of these processes is expected to be commercially viable before 1980. One advantage of a very stringent control standard for fluorides, of course, is to spur the development of a process that is pollution-free. Even so, the two processes described above would probably still not be available before 1980. The prospective smelter owner, therefore, does not truly have the alternative of a non-polluting process for the production of aluminum and must consider other alternative courses of action.

Another alternative open to the prospective smelter owner is to build a conventional smelter in the United States and increase prices by an amount sufficient to cover his emission controls costs. In order to more readily accomplish this objective, the smelter must be integrated into fabricating. It would also be advantageous if the proposed new smelter were to be built by a firm that had considerable existing fabricating capacity. These conditions are necessary because a commodity market exists for aluminum ingot. Differences in ingot between producers for a given grade of material do not exist. Any one producer cannot unilaterally increase prices unless the other producers follow. It is doubtful that other producers, given that they are facing controls on their existing facilities that are less costly than the controls on a new source smelter, would go along with a price increase. So long as they were not operating at capacity , existing smelters would probably hold prices down in the hope of generating additional volume. As more and more new smelters were constructed, however, the upward pressure on primary ingot prices could possibly be relieved by a price increase. The extent of the increase would depend upon the level of foreign prices and the degree of foreign competition. If the owner of the new smelter were integrated into the fabricating market where some degree of product differentiation does exist, then it might be possible to increase prices on a fabricated product or products that would be enough to recover the additional emission control costs. A large amount of existing fabrication would mean that a lower per-unit increase would be needed in order to recover the emission control costs. It must be concluded, therefore, that a single new smelter that did not control a fabrication facility would be in a difficult position with regard

to passing on emission control costs when compared to a large, integrated smelter that is increasing capacity only marginally. Of course, even the large, integrated smelter would have a limit on the amount of additional costs that could be passed on. That limit would vary from firm to firm, and no attempt has been made at this time to determine its magnitude.

Another alternative open to the prospective smelter owner would be to build a conventional smelter in the United States and absorb the additional emission control costs. This alternative is again more feasible for a company that has a large amount of existing smelting capacity, as long as this capacity is earning an acceptable rate of return. A smelter operator, particularly if he envisions increased prices in the future for his product, may temporarily accept a lower rate of return on his new smelter in order to increase his capacity and his total profits. Again, if he has a large amount of existing capacity which is earning an acceptable return, then the dilution in earnings from the new smelter is relatively less. Table 22 summarizes the return on equity alternatives that would apply to different hypothetical aluminum smelters. The price of 29.5¢/lb was chosen because it appeared to be the market price required to generate new smelter construction. Assuming a price of 29.5¢/lb for ingot, the company that adds 150,000 tons/year of prebake capacity to 1,000,000 tons/year of existing capacity would see after-tax return on equity reduced to 9.8 percent from 10.0 percent. The new smelter, however, would have an after-tax return on equity of only 8.4 percent. It is doubtful that the reduction in return on equity from 10.0 to 9.8 percent would deter the existing smelter owner from adding some additional capacity.

Table 22. SAMPLE RETURN ON EQUITY CALCULATIONS

Return on Equity @ 29.5¢/lb:	CASE I[a]	CASE II[b]	CASE III[c]
Total Capacity (Tons)	1,000,000	150,000	1,150,000
Equity Capital Before Additional Control[d]	$750,000,000	$112,500,000	$862,500,000
Additional Control Capital (Prebake Level #2)	-0-	5,175,000	5,175,000
Total Capital - $ (Equity)	$750,000,000	$117,675,000	$867,675,000
- ¢/lb Capacity	37.50	39.23	37.73
Operating Cost Before Additional Control (¢/lb)[e]	22.00	22.00	22.00
Additional Control Cost (Prebake Level #2)	-0-	0.89	0.12
Total Cost (¢/lb)	22.00	22.89	22.12
Net Before Tax Revenue @ 29.5 ¢/lb	7.50	6.61	7.38
Net After Tax Revenue (50% Rate) (¢/lb)	3.75	3.30	3.69
Return on Equity Capital[f]	10.0%	8.4%	9.8%

[a]Case I: Smelter not required to meet new source performance standard; incurs only existing industry average emission control costs.

[b]Case II: Smelter meets Prebake Level #2 control requirements; represents a new entrant to market.

[c]Case III: Sum of Case I and Case II; represents company with existing capacity that builds a new smelter.

[d]Assumes $1500/ton total capital for smelter, bauxite, and alumina facilities; 50% equity capital.

[e]EPA assumption.

[f]It would be possible for the new market entrant to achieve a return on equity of 10% if it could lower its equity portion of the total capital requirement to 42% instead of 50%.

There is a great deal of doubt, however, that a return on equity of 8.4 percent would encourage a new entrant into the primary aluminum market. The historical average return on equity for three major producers has only averaged 7.6 percent over the past 7 years (refer to Table 23), but this is primarily due to the exceptionally low return on equity generated in 1971 and 1972. Excluding these 2 years, the average return on equity increases from 7.6 to 9.4 percent.

The following table is obtained from Table 22 by substituting the incremental capital and operating costs for the proposed standard and Control Level #3 for the costs of Control Level #2:

Return on Equity Capital @ 29.5¢/lb	Case I	Case II	Case III
1) Proposed Standard	10.0%	9.7%	10.0%
2) Control Level #2	10.0%	8.4%	9.8%
3) Control Level #3	10.0%	7.5%	9.7%

It can only be concluded that a single new source smelter would probably not enter the primary aluminum market if faced with a level of control more stringent than the proposed standard. A large, integrated smelter, however, would have much less difficulty meeting any standard shown above, although the exact level that could be met would depend entirely upon the costs structure and size of the individual firm and the amount of incremental capacity added. At the cost level of the proposed standard, however, the difference in return on equity capital between the existing firm and the entrant is minor.

Table 23. HISTORICAL RETURN ON EQUITY IN THE ALUMINUM INDUSTRY (THREE MAJOR PRODUCERS)

	Net Income After Taxes[a]	Total Stockholder Equity[a]	% Return On Equity
1966	$229.3	$1998.1	11.5
1967	213.6	2143.8	10.0
1968	187.3	2245.5	8.3
1969	247.1	2447.9	10.1
1970	193.2	2575.9	7.5
1971	78.3	2588.0	3.0
1972	118.1	2652.4	4.5
Average	$181.0	$2378.8	7.6

[a]In millions of dollars

SOURCE: Moody's Industrial Manual (1973)

Another alternative that could be pursued by the prospective new source smelter owner would be to build a smelter in Canada. A large number of domestic smelters are now located in the Pacific Northwest, primarily because of the relatively low power costs available there. If the cost structure of a new source smelter in the Pacific Northwest is compared to a similar-sized smelter in British Columbia, then it must be concluded that the only difference in cost structure between the domestic smelter and the Canadian smelter, both of which are selling their output in the United States, would be the current 1¢/lb import duty on aluminum ingot. Costs for power, alumina, other raw materials, labor and overhead, and capital-related charges should be approximately the same. This means that in the United States costs would have to increase by approximately 1¢/lb in order to make location of the smelter in Canada a viable alternative. If the new source smelter is assumed to be of the prebake variety, then the following table can be constructed:

Cost Differential

U. S. vs. Canada

Canadian Control Level	Prebake Proposed Std (0.63¢/lb)	Prebake Level #2 (1.43¢/lb)	Prebake Level #3 (2.18¢/lb)
1. Canadian standard equivalent to current domestic control level (0.54¢/lb)	0.09¢/lb	0.89¢/lb	1.64¢/lb
2. Canadian standards equivalent to level of proposed standard for prebake (0.63¢/lb)	-0-	0.80¢/lb	1.55¢/lb

At a level of control less stringent than Control Level #3, probably no shifting of domestic smelter capacity to Canada will be observed because the pollution cost differential between the United States and Canada is less then 1¢/lb of aluminum. At Control Level #3, however, the incentive to shift domestic smelting capacity to Canada is significant.

The choice of a future site for a primary aluminum smelter is not necessarily only between the United States and Canada. Other countries present attractive alternatives when total smelting cost is being considered. The following is an excerpt from a report by Arthur D. Little, Inc., on the aluminum industry. Although some of the numbers used in this report may be somewhat dated by now, the following comments are still pertinent:

"Today an international company has four principal choices of location:

- The United States, which has a major nearby market, but depends upon premium-priced power, imported alumina, and limited government subsidies.
- Continental Europe, where power is even more expensive, but which offers good markets and significant government subsidies.
- Countries with cheap power and government loans; but no markets and high infrastructure costs (e.g., in Africa or the Middle East).
- Australia, with abundant raw material, but not particularly cheap power, high infrastructure costs, and distant markets."[15]

The report goes on to state: "Power costs show the widest variation among areas, and also from one location to another within each area. The Middle East's vast supplies of oil and gas will probably keep it in the lowest cost area, although there are a small number of hydro sites elsewhere that can also produce power for 2.5 mills. Europe is generally the highest cost area. . . . Smelters close to raw materials include significant freight and tariff costs on ingot, which offset savings on shipping alumina, while the situation is reversed for smelters located near large markets. . . . The theoretically lower wage rates of developing areas have usually been offset by the need to pay more for skilled personnel, though recent contract settlements may well put total U. S. labor costs above any others. . . . Capital charges are a very significant element of smelter costs. . . . As pollution laws are tightened, capital costs in the United States and Europe may rise even higher."[13]

The question of smelter location is thus rather complex and depends upon many factors other than pollution control costs. It is safe to say that any domestic emission control regulation that requires an expense greater than what would be experienced in another country is an incentive for the smelter owner to locate his facility in that other country. An exact quantification of the impact of the proposed emission standard, relative to power costs, raw material costs, and all other location-related factors, is not possible at this time. There is currently a trend for companies to consider locating smelters outside

the United States. Alcoa, for example, has partial ownership of smelters in Mexico, Australia, Brazil, and England. Reynolds Metals has partial ownership of smelters in Canada, Venezuela, and England. Kaiser Aluminum has partial ownership of smelters in Australia and Ghana. It is not expected that an acceleration of this trend toward locating smelters outside the United States would be caused by the proposed standard for fluoride emissions from new source smelters, since there is so little cost difference between current industry practice and the proposed standard. More stringent control levels, however, may well accelerate the trend toward location of smelting capacity overseas.

The last alternative that the prospective smelter owner might choose is not to build a smelter at the present time. This would mean that domestic aluminum needs would have to be supplied by imports. Table 20 shows that total primary ingot supplies in 1980, including stockpile sales, will be 7,990,000 tons. If we assume that stockpile sales remain at 77,000 tons and that the 1977 capacity of 5,436,000 tons is not increased by 1980 and is utilized at 100 percent of capacity, then imports must increase from 1,100,000 tons to 2,477,000 tons. This additional amount of imports, valued at 25¢/lb, would have a negative impact of $688.5 million on the balance of payments account. It is doubtful, however, that foreign producers would be able to supply this increased amount of primary aluminum to the United States. Foreign production capacity has greatly expanded in the past few years, but there is every indication that foreign demand is catching up

with the foreign capacity increases. This means that the United States would probably not be able to depend upon foreign imports to such an extensive degree. This situation of increased demand relative to supply would result in increased prices for aluminum. These increases would mean that producers could then afford the emission control equipment and still make an acceptable profit. Presented below is a summary of the prices needed to generate a return of 10 percent on equity to the smelter owner. (A return of 10 percent on equity is assumed to be the cut-off point in the decision to build a new smelter.)

	Ingot Price Required to Yield 10% Return on Equity (Prebake Process)[a]		
Case	Proposed Standard	Control Level #2	Control Level #3
I-Existing capacity of 1,000,000 tons/year	29.5¢/lb	29.5¢/lb	29.5¢/lb
II-New smelter with capacity of 150,000 tons/year	29.7¢/lb	30.7¢/lb	31.8¢/lb
III-Combination consisting of 1,000,000 tons/year of existing capacity plus 150,000 tons/year of new capacity	29.5¢/lb	29.7¢/lb	29.8¢/lb

[a]Based on data presented in Table 22.

For adding smelting capacity the firm with existing capacity subject to lower emission control costs would have an advantage over a brand-new market entrant. At the level of the proposed standard, very little difference exists between the brand-new smelter and the existing smelter with additional capacity, but the differences

become appreciable at Control Level #2 and Control Level #3. At Control Level #2 the brand-new smelter needs a price of 30.7¢/lb to realize a price of 31.8¢/lb vs. 29.8¢/lb for the smelter adding 15 percent additional capacity. Since a price of only 29.5¢/lb is required for a 10 percent return on equity for a smelter that only has to meet current industry control costs, then it is seen that the impact of the various control levels on the large firm with existing capacity is minimal. It must be concluded that since the proposed standard will require approximately the same break-even price for either the new smelter or the smelter with incremental capacity, then no barriers to new market entrants exist. At more stringent control levels, however, new entrants would definitely tend to be excluded.

One point that recurs throughout the above analysis is that the small firm is generally at a disadvantage when competing with a large, established firm when control levels more stringent than the proposed standard are considered. At the cost level of the proposed standard, essentially no difference exists between the new entrant and the large, established producers. This conclusion hinges upon the assumption that the existing smelters will not be required to adopt controls more costly than what are currently being incurred to meet most existing state standards. The advantage enjoyed by large, established firms would diminish considerably if they were forced to incur a higher level of costs than they are currently experiencing. This analysis has assumed that state regulations will require a cost outlay essentially equivalent to what the industry is currently spending. The impacts discussed

above would have to be modified, of course, if state standards were to become more stringent, but the basic conclusions would tend to remain unchanged.

In summary, the analysis of the impact of alternative levels of emission control upon the domestic primary aluminum industry leads to the following conclusions:

1. Emission controls at a level of stringency equal to or greater than the proposed standards will accelerate the current industry trend toward the utilization of only the prebake process at new source aluminum smelters;

2. Emission controls at a level of stringency equal to the proposed standard will have no adverse impact upon future growth in the domestic aluminum industry;

3. Emission controls that are more stringent than the proposed standard will tend to discriminate against the small market entrant that is without existing capacity in favor of the large, established, integrated producer;

4. Emission controls that are more stringent than the proposed standard will tend to encourage a greater proportion of imports of primary ingot than would normally be the case;

5. Emission controls more stringent than the proposed standard would encourage higher domestic prices for primary aluminum ingot and fabricated products than would normally be the case.

H. Summary

During initial plant surveys, source measurements, and a later visit to Norway,[11] seven primary aluminum reduction plants were observed to have visible emissions of about 10 percent opacity or less; four which had dry control systems had no visible emissions.

One domestic carbon anode bake plant had visible emissions of less than 20 percent opacity. Thirty hours of recorded visible emissions taken by EPA at another domestic plant showed visible emissions of about 10 percent. The Norwegian anode bake plant had visible emissions of about 10 percent.

The proposed standard is based on the following:

1. Primary emissions which averaged less than 0.5 lb TF/TAP were achieved on four different plants in measurements performed by EPA.

2. One foreign plant reports primary emissions of less than 0.5 lb TF/TAP. (Although another foreign plant reports primary emissions at 0.74 lb TF/TAP, its total fluoride emissions over 18 months of operation averaged 1.92 TF/TAP, below the proposed standard.[10])

3. Three of the six tests of secondary systems by EPA showed average emissions of less than 1.25 TF/TAP, including the two plants with elaborate sampling and flow measurement devices.

4. Based on an assumed fluoride control efficiency of only 90 percent (compared to demonstrated 99.5 from primary control systems), emissions from carbon bake plants can be controlled to below 0.20 lb TF/TCAP (0.10 lb TF per ton of aluminum equivalent).

5. Data have been obtained from plants in which the collection systems were upgraded and the control systems retrofitted to an existing plant. New plants, engineered from inception with environmental considerations, should easily be able to achieve the recommended standard of performance.

6. The economic impact upon the domestic primary aluminum industry of the proposed standards of performance is not considered to be adverse. Even though Soderberg process smelters will probably not be built in the future due to the cost of achieving the proposed standards, the prebake process will still be a viable alternative.

7. The economic impact upon the domestic primary aluminum industry and the general public would be adverse if standards of performance more stringent than the proposed standards were to be imposed upon the industry. The negative economic factors include the increased amount of imports of primary aluminum, higher prices for both ingot and fabricated materials than would normally be the case, and increased difficulty of market entry or capacity addition for the small smelter owner as opposed to the large, integrated smelter owner.

The proposed standard of 2.0 lb TF/TAP is supported by measurement of emissions from potrooms by EPA on Plants A, B, C, and D as shown in Figures 11 and 12. Based on a conservative estimate of 90 percent efficiency, control technology for anode bake plants is available to achieve 0.20 lb TF/TCAP. The standard will require installation and proper maintenance of equipment representative of the best technology which has been demonstrated for the industry. In the Administrator's judgment, the achieveability and reasonableness of the proposed standards has been adequately demonstrated.

REFERENCES

1. Singmaster & Breyer, Air Pollution Control in the Aluminum Industry, Contract No. CPA 70-21, Environmental Protection Agency, July 23, 1973.

2. Data submitted to EPA by primary aluminum companies.

3. Primary Aluminum Industry (Draft Copy). Contract No. CPA 70-142, Task Order No. 2, Environmental Protection Agency.

4. Oelschlarger, W., "Determination of Fluoride Standards for Vegetation and Animals," Fluoride (Journal of International Society for Fluoride Research), Vol. 5, No. 3, July 1972, p. 111.

5. Antonelli, Dr. Giuseppe, "Effects of Fluorine in the Regions Close to Industries That Produce It . . .," (Rass. Trim. Odant., Vol. 35, No. 2, April-June 1954, pp. 95-122 (Italian-English translation obtained from EPA Air Pollution Technical Information Center).

6. "National Emission Standards Study," Senate Document No. 91-63, U. S. Government Printing Office, Washington, D. C., 1971.

7. Fluorides, National Academy of Sciences, Washington, D. C., 1971.

8. Stern, Arthur C., Air Pollution, Second Edition, Volume 2.

9. Letter from the State of Oregon Department of Environmental Quality, dated August 7, 1973.

10. Data submitted to EPA by European primary aluminum producers.

11. Report on trip to Norway, Roger O. Pfaff, EPA, August 22-25, 1972.

Reproduced from best available copy.

12. Bellack, E. and P. J. Schoubue, "Rapid Photometric Determination of Fluorides in Water." Analytical Chemistry, 30, pp. 2032-2034, 1958.

13. Aluminum Industry Outlook to 1980, Arthur D. Little, Inc., August 1971.